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PARTS OBSOLESCENCE MANAGEMENT TECHNOLOGY TRANSITION (POMTT)

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MATERIALS AND MANUFACTURING DIRECTORATE
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This report has been reviewed and is releasable to the National Technical Information Service (NTIS). It will be available to the general public, including foreign nationals.

This technical report has been reviewed and is approved for publication.

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This report is published in the interest of scientific and technical information exchange and does not constitute approval or disapproval of its ideas or findings.

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Obsolescence impacts everything, especially in the Defense Industry. The reduction of sources and availability affects component parts, assemblies, software, and even complete systems. Changes in the commercial and military marketplace have also resulted in military-grade parts becoming less available. These obsolete high-reliability components are now too expensive to reproduce, and often less reliable than new commercial parts that perform the same function. As a result, manufacturers of high reliability weapon systems must now use commercial parts for their military applications.

The Air Force established the Electronic Parts Obsolescence Initiative (EPOI) in 1998 to help address these problems, and specifically support the mitigation of obsolescence. Tools, technologies, and methodologies were established and funded; and follow-on pilot demonstration programs were also established to evaluate the performance and commercial viability of these tools.

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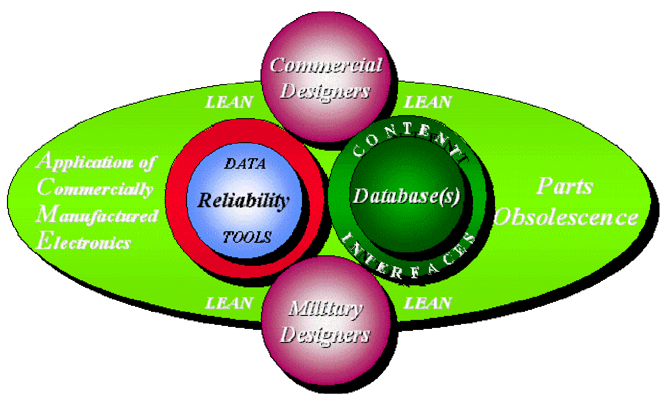

MANTECH

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This report is the final contractual deliverable in a series of quarterly submittals covering Lockheed Martin Corporation's (LMC) Parts Obsolescence Management Technology Transition (POMTT) cooperative agreement program. It includes accomplishments and program progress from September 8, 1999 to August 31, 2004. The final report is organized into several sections:

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Acronyms

ABEL - Advanced Boolean Expression Language

ACE - Alternate Component Expert

ACME - Application of Commercially Manufactured Electronics

ACME/PO - Application of Commercially Manufacturing Electronics / Parts Obsolescence

AFRL - Air Force Research Laboratories

AFTOC - Air Force Total Ownership Cost

ALC - Air Logistics Centers

AOA - Automated Obsolescence Assessment

APMC - Avionics Process Management Committee

AQEC - Approved Qualified Electronic Components program

ASC - Aeronautical Systems Center

ASIC - Application Specific Integrated Circuit

AVDLR - Aviation Depot Level Repairable

BAE - BAE Systems Controls

BC - Bus Controller

BGA - Ball Grid Arrays

BOM - Bill-of-material

BPR - Behavioral Product Reengineering (Synopsis)

CAIG - Cost Analysis Improvement Group

CAIV - Cost as an Independent Variable

CAST 2000™ - COTS Assessment and Selection Technique

CBO - Congressional Budget Office

CER – Cost Estimation Relationship

CM - Cost Methodologies

COMAND - Component Obsolescence Management Database

COTS - Commercial Off-The-Shelf

cPCI - CompactPCI®

DFF – Delay Flip Flops

DLA - Defense Logistics Agency

DLIS - Defense Logistics Information Service

DLSC - Defense Logistics Service Center

DMS - Diminishing Manufacturing Sources

DMSMS - Diminishing Manufacturing Sources and Material Shortages

DoD - Department of Defense

DSCC - Defense Supply Center Columbus

DVTG - Design Verification Test Generation Tool

ECIU - Enhanced Central Interface Unit

EOL - End of Life

EPI BP - Engineering Process Improvement Best Practices

EPOI - Electronic Parts Obsolescence Initiative

FC - Fibre Channel

FCC - Fire Control Computer

FLIS - Federal Logistics Information System

GAC - General Avionics Computer

GEIA - Government Electronics Industry Association's

GIDEP - Government - Industry Data Exchange Program

HDL - Hardware Description Language

IC - Integrated Circuit

ICE - Integrated Cost Estimation

IP - Intellectual property

IWTA – Inter-company Work Transfer Agreement

LANTIRN™ - Low Altitude Navigation and Targeting Infrared for Night

LCC - Life Cycle Costing

LCM - Life Cycle Manager

LINK - Logistics Information Network

LMC - Lockheed Martin Corporation

LMM&FC-D - Lockheed Martin Missiles and Fire Control – Dallas

LMM&FC-O - Lockheed Martin Missiles and Fire Control – Orlando

LMNE&SS - Lockheed Martin Naval Electronics and Surveillance Systems

LOT - Life of Type

LRU - Line Replaceable Unit

MANTECH - Manufacturing Technology

MCES – Mission Critical Enterprise Support

MOCA – Mitigation of Obsolescence Cost Analysis

NGIT - Northrop Grumman Information Technology

NMCI - Navy-Marine Corps Intranet

NPI - New Product Introductions

NSN - National Stock Number

O&S - Operation and Support

ODT - Obsolescence Decision Tool

OEM - Original Equipment Manufacturers

OFP - Operational Flight Program

OM - Obsolescence Management

OSA - Open Systems Architecture

P3I - Pre-Planned Product Improvement

PASES - Physics of Failure Approach to Sustainable Electronic Systems

PCI - Peripheral Component Interconnect

PCN - Product Change Notices

PEM - Plastic Encapsulated Microcircuit

PHM - Parametric Hardware Models

PO - Parts Obsolescence

PODM - Parts Obsolescence Decision Model

POET - Parts Obsolescence Engineering Toolkit

POMT - Parts Obsolescence Management Technology

POMTT - Parts Obsolescence Management Technology Transition

QML - Qualified Manufacturer Lists

R2T2 – Rapid Response Technology Trade Tool

RADSS - Resource Allocation Decision Support System

RADSS 2000 – Resource Allocation Decision Support System (Year 2000 version)

RT - Remote Terminal

RTOC - Reductions in Total Ownership Cost

SLDL - System Level Description Language

SLEP - Service Life Extension Program

SLOC – Source Lines of Code (A metric for Developed Software size)

SLTA - System Level Test Automation

SMD - Standard Microcircuit Drawings

SME - Subject Matter Expert

SPO - System Program Office

SRM – Supplier Relationship Manager

TacTech - Transition Analysis of Component Technology

TADS/PNVS - Target Acquisition Designation Sight/Pilot Night Vision Sensor

VAMOSC - Visibility and Management of Operating and Support Costs

VHDL - Very high-speed integrated circuit Hardware Description Language

VHSIC - Very High-Speed Integrated Circuit

Section 1

Overview

Obsolescence impacts everything, especially in the Defense Industry. The reduction of sources and availability affects component parts, assemblies, software, and even complete systems. Changes in the commercial and military marketplace have also resulted in military-grade parts becoming less available. These obsolete high-reliability components are now too expensive to reproduce, and often less reliable than new commercial parts that perform the same function. As a result, manufacturers of high reliability weapon systems must now use commercial parts for their military applications.

Original Equipment Manufacturers (OEM) of military weapon systems continue to push for newer and more reliable products; commercial products now represent the leading edge of technology in many areas. However, many key commercial parts have extremely short life spans (sometimes as short as 18-36 months) and, unfortunately, this equates to more rapid obsolescence. The increased usage of commercial parts also magnifies the obsolescence problem since the larger demand results in a decreased potential supply. Seventy to eighty percent of all military system lifecycle costs occur after delivery of the product, so the Department of Defense (DoD) has a significant interest in eliminating or mitigating obsolescence, and reducing its risk. In many cases, the effects and risks associated with obsolescence cannot be removed, so they must be managed and reduced through the use of newly developed tools, techniques, and procedures.

The Air Force established the Electronic Parts Obsolescence Initiative (EPOI) in 1998 to help address these problems, and specifically support the mitigation of obsolescence. Tools, technologies, and methodologies were established and funded; and follow-on pilot demonstration programs were also established to evaluate the performance and commercial viability of these tools.

As part of these demonstration programs, the Lockheed Martin POMTT Team implemented a total of ten pilot evaluations to apply the tools, demonstrate their capabilities, and document their cost-effectiveness. These pilot evaluations consisted of:

- Georgia Tech's Physics of Failure (PoF) analysis of BAE Full Authority Digital Engine Control (FADEC) which is used on the C-17, F-35, F-18, and A-10
- i2 Technologies' Supplier Relationship Manager (SRM) Life Cycle Prediction of Lockheed Martin Corporation's (LMC) Joint Air-to-Surface Strike Missile (JASSM) components
- The University of Maryland's Mitigation Obsolescence Cost Analysis (MOCA) Obsolescence Planning as applied on LMC's Target Acquisition and Designation Sight Modernization (MTADS) Program

- VP Technologies' redesign of Lockheed Martin's Longbow Missile Video Logic Driver Hybrid ASIC
- Boeing Small Scale Electronics Development's (SSED) retargeting of LMC's Hellfire Missile Automatic Gain Control (AGC) Pre-Amp ASIC
- Northrop Grumman Information Technology's (NGIT) Resource Allocation Decision Support System (RADSS) decision modeling for LMC's Low Altitude Navigation Targeting Infrared for Night (LANTIRN) / InfraRed Search and Track (IRST) system
- Integration of The University of Maryland's MOCA and Frontier Technology's (FTI) Integrated Cost Analysis (ICE) cost analysis tools for LMC's F-16 Program
- EDAptive's automatic test vector generation for Lockheed Martin's TACtical Missile System (TACMS)
- i2 Technologies Automated Obsolescence Assessment (AOA) for LMC's F/A-22 program
- Northrop Grumman Information Technology's RADSS decision modeling of LMC's PCB Manufacturing Technology (Production Resource Allocation Automation, PRADA)

These projects are defined in greater detail in later sections.

1.1 Goals and Objectives

The overall goal of the program was to integrate new business and engineering tools and processes in order to more effectively manage electronic component obsolescence. The project would also help to demonstrate cost reductions through the creation of business cases resulting from applying the tools on multiple Lockheed Martin Corporation production programs. These business cases would then make a case for tool application to reduce total Operations and Support (O&S) costs to LMC's customers. This improved obsolescence management would also enable greater mission readiness and increase the life of fielded weapon systems at an affordable cost (see Figure 1.1 below).

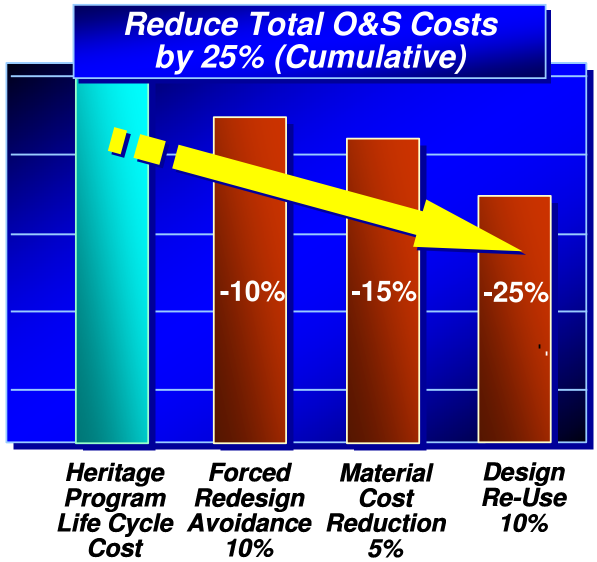


Figure 1.1 – O&S Cost Reduction Estimates

All of this would be accomplished through benchmarking existing processes, lessons-learned, and technologies. Evaluation of current risk mitigation approaches, cost evaluations and analyses, the establishment of metrics that are quantifiable, and measurable, and the inclusion of design cycle times would also help develop the business Cases.

After the benchmarking, an evaluation of the tools and technologies provided by the EPOI program would begin. This consisted of analysis of each of the tools and technologies, their potential benefits (cost, time, performance, etc.), their drawbacks (availability, cost, acceptance, etc.), and the potential programs that were to use them.

After the best tool/program combinations were selected, the pilots were submitted for approval and implementation. The teams would evaluate the improved/decreased performance as a result of the tools and provide feedback and process improvement to the developer and other Lockheed Martin participants for tool refinement, training, and support.

The expected benefits to LMC and its customers included the interception of electronic component obsolescence issues earlier in their life cycle to allow programs to perform the lowest cost life cycle solutions. This would also help minimize delivery schedule disruptions (line stoppages) and lower maintenance costs. Capabilities such as obsolescence prediction would help mitigate future risks, avoid forced redesigns, and allow more accurate pricing of follow-on contract options and spares. This would also help the insertion of commercial technology and advanced packaging concepts and allow greater flexibility in meeting and exceeding system performance requirements. Other areas such as enhanced physics of failure models would reduce risks in using lower cost commercial components, especially on programs with warranties, and help quantify the risks associated with long term storage (latent defects).

Section 2

Program Background

This section provides history and background information on the overall initiative as well as specific details on the POMTT program including structure, makeup, and participation.

2.1 EPOI

In 1998, the Air Force Research Laboratories (AFRL) MANTECH (Manufacturing Technology) division in Dayton, Ohio established the Electronic Parts Obsolescence Initiative (EPOI) to help the DoD and the defense industry manage and minimize the effects of obsolescence on programs and systems through the development of tools, technologies, and methodologies. It was created as a five-year project aimed to help ensure mission readiness and increase the life of fielded weapons systems at an affordable cost. This was to be achieved through improved parts obsolescence management capabilities. EPOI provided initial and advanced development funding for a series of management and re-engineering tools that could be applied to all defense systems affected by parts obsolescence. The initiative also helped to develop new physics-of-failure based reliability models for the assessment of commercially manufactured electronics. The final task of the initiative was to perform pilot demonstration programs to evaluate the viability and successful transition of these tools, best practices, and technologies to the defense industry. The development of the tools and their evaluation comprised the areas in which Lockheed Martin would participate.

The initiative consisted of nine programs in four key areas. Each of the programs focused the development of new and existing tools and technologies towards the obsolescence problem as follows:

- Electronics design for discrete Integrated Circuits (ICs) and systems
- Mixed-signal (analog and digital) microcircuit design and application
- Legacy data capture and design extraction
- Reliability modeling for commercial Plastic Encapsulated Microcircuits (PEMs) and Ball Grid Arrays (BGAs)
- Obsolescence decision analysis and optimization
- Standardized data capture and information exchange
- Obsolescence prediction and monitoring
- Technology refreshment planning

Some of these were created as commercially available tools (such as obsolescence prediction, electronic design, and technology refreshment). Others (design extraction and mixed-signal design) are now provided as a service obtained from the developer.

The development contracts were created to help provide new tools/technologies, allow continued development of existing tools and technology, and apply an existing tool or technology to the obsolescence problem. Programs with the following companies in the first three areas were established as follows:

Area 1 - Parts Obsolescence Management

COMPANY	PROGRAM
VP Technologies	Electronic Virtual Design and Design Extraction
TRW	System Level Design Methodologies and Tools
i2 Technologies (formerly Aspect Development)	Database Management and Obsolescence Prediction
Northrop Grumman Information Technologies (formerly Litton TASC)	Decision Optimization

Area 1 consisted of a variety of tools and technology development intended to aid OEMs and the defense industry in more quickly solving obsolescence issues. These support both the proactive and reactive design of systems, would help mitigate future obsolescence, and would provide faster, more accurate solutions for existing obsolescence.

Area 2 - the Application of Commercially Manufactured Electronics (ACME)

COMPANY	PROGRAM
Boeing	Reliability Modeling and Mixed-Signal ASIC Design
Motorola	Commercial Semiconductor Reliability Modeling
Northrop Grumman / **Averstar** (formerly Titan Systems)	Rosetta Programming for Data Sharing
Northrop Grumman / **Georgia Technological University**	Physics of Failure-Based Reliability Modeling for Microcircuit Ball, and Column Grid Arrays

Area 2 focused on commercially manufactured electronics and their application in military and defense systems. The approach was through the development of reliability analysis and component data for commercial parts. Since the removal of military specifications in the late 1990s, the defense industry must increasingly rely on Commercial Off-The-Shelf (COTS) components that may have the same or better reliability and performance, but are no longer intended or warranted by their manufacturers for these types of applications.

Area 3 - Cost Methodologies

COMPANY	PROGRAM
Frontier Technologies and The University of Maryland's CALCE Center	A Gap and Integration Analysis of Obsolescence Cost Analysis Tools

Area 3 concerns the application of obsolescence management to cost analysis. This new capability takes into account obsolescence prediction and increasing costs from parts becoming obsolete during system production.

Area 4 - Pilot Demonstration Programs

CO-AWARD WINNERS	
TEAM/COMPANY	**PROGRAM**
Prime **Lockheed Martin Missiles and Fire Control – Orlando (LMMFC-O)** **IWTAs** **Lockheed Martin Missiles and Fire Control – Dallas (formerly Lockheed Martin Vought Systems) (LMMFC-D)** **Lockheed Martin Maritime Systems and Sensors (MS2)** **BAE Systems Controls (BAE) (formerly Lockheed Martin Control Systems)**	Parts Obsolescence Management Technology Transition (POMTT)
Prime **Northrop Grumman Technologies (NGT)**	Parts Obsolescence Management Technology (POMT)

The fourth area addressed AFRL's need to evaluate their investment in order to determine the cost payback value, incentivize industry, and adopt those tools that were most viable in the commercial marketplace. This consisted of pilot demonstrations on military production programs at Lockheed Martin and Northrop Grumman. They were co-awarded contracts to engage the tools and technologies, to determine the best for their particular needs, and apply them to Technology and Production level pilot evaluations. Technology pilots applied the tools and evaluated the results, but did not directly make or affect any system production changes. The Production pilots used the results of the selected tool or technology to make changes to the system either through parts lists changes, scheduling modifications, part applications, planning decisions, or other changes to the hardware.

Lockheed Martin contracted to select and implement a minimum of six total Pilot programs to apply the tools, demonstrate their capabilities, and document their cost-effectiveness. Lockheed Martin's goal was to implement those most viable into their programs, processes, and business policies to improve their obsolescence-management capability overall. Ultimately their military services customer would reap the end-user benefit.

This total overall EPOI program was a five-year, $32 million initiative that ran from September 1999 to August 2004. The EPOI - PO/ACME evaluated tools and technologies are detailed in **Section 6**, and those Lockheed Martin selected specifically for Pilot demonstrations are presented in **Sections 7 and 8**.

2.1.1 Parts Obsolescence (PO)

The **PO** initiative was established to promote development and evaluation of as many alternatives as possible for a given parts obsolescence situation. It has been found that individual case circumstances will make some alternatives more attractive than others. Analysis of each practical option takes into account cost, execution time frames and technical risk to make an efficient resolution decision. A number of parts obsolescence alternatives exist which may be used singly or in combination.

2.1.2 Application of Commercially Manufactured Electronics (ACME)

The **ACME** series of contracts established by the Air Force Research Laboratory (AFRL) provided investment for development commercial tools and methods that can be applied to the industry. The effort included validating reliability prediction tools, packaging and assembly of commercial ASICs, and improving access to commercial ASICs vendors.

2.1.3 Parts Obsolescence Management Technology Transition (POMTT)

Lockheed Martin's **POMTT** program focused on the evaluation of the ACME/PO tools and technologies, and transitions them to use in actual weapon system design and production. It also was intended to foster the creation of new software, metrics, processes, and strategies for use in reducing program lifecycle costs resulting from component obsolescence. Efforts were focused on providing flexible sustainment and reactive obsolescence solutions for heritage programs, as well as developing proactive planning and sound COTS strategies for new programs. The initiative also used pilot demonstration programs to ensure the successful demonstration and transition of the best business practices, tools, and technology developed by the initiative.

Software and techniques that were developed as part of the pilots were also validated through the demonstrations. These pilot programs brought about technology insertion into systems, and development and documentation of obsolescence management business cases. This helps ensure reliable application of commercial electronics in military systems and maximizes the cost avoidance of COTS while providing a corporate approach to managing obsolescence.

An additional program began in 2004 to integrate the obsolescence management skills and lessons learned developed on POMTT proactively into every step of the product development process. This effort, consisting of the lessons learned, selected viable tools, and newly developed practices, builds on the EPOI initiative and provides a framework for future development of obsolescence management at Lockheed Martin.

2.2 POMTT Team Members

The POMTT Team is made up of several different Lockheed Martin Sites and includes a former Lockheed Martin facility that was sold to BAE. Lockheed Martin Missiles and Fire Control facility in Orlando (LMMFC-O) was the Contract Prime and was responsible for overall contract management and performance.

2.2.1 Lockheed Martin Corporation

Lockheed Martin is a leading technology and systems integrator which provides complex solutions and services for Government and commercial customers worldwide. It is a multinational organization with 939 facilities in 457 cities and 45 states throughout the U.S.; and internationally with business locations in 56 nations and territories.

In calendar year 2003, LMC had sales surpassing $31 billion and employed over 130,000. Its core business areas include aeronautics, space systems, technology services, global telecommunications, and systems integration. Lockheed Martin has successfully managed many major defense programs through the complex process of development, deployment, and long-term logistics and technical support.

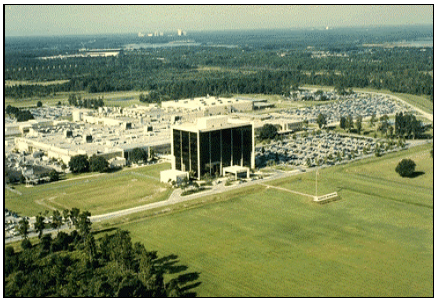
Lockheed Martin Missiles and Fire Control is an experienced systems integrator, weapons system developer, and manufacturer, with major centers in Orlando and Dallas. Major programs, as illustrated in Figure 2.1, span research and development through production and field support of major missile systems, smart munitions, and fire control systems. The company is the corporation’s lead business unit for research, development, and production of electro-optic and smart munitions systems, and is a pioneer in the field of versatile, high-performance missile and rocket technology.

Figure 2.1 - Lockheed Martin Missiles and Fire Control Programs

Major programs include: Copperhead, Navy GP, Hellfire, Longbow, Javelin, Joint Air-to-Surface Standoff Missile (JASSM), Wind Corrected Munitions Dispenser (WCMD), Pershing, and PATRIOT in Orlando; and Multiple Launch Rocket System (MLRS), Army Tactical Missile System (ATACMS), Patriot Advanced Capability (PAC-3) missile, Powered Low-Cost Autonomous Attack System (LOCAAS), and Line-of-Sight Anti-Tank (LOSAT) in Dallas. M&FC is also a world leader in fire control systems for rotary- and fixed-wing platforms. Successful programs include Target Acquisition Designation Sight/Night Vision Sensor (TADS/PNVS), modernized TADS/PNVS and Longbow for the AH-64D Apache, Hawkeye Target Sight System (TSS) for the AH-1Z Cobra, LANTIRN for the F-16, F-15, and F-14 fighters and other aircraft, and Sniper XR for the next generation of jet fighters.

LMMFC-O, prime contractor for POMTT, is an industry leader in technologies related to electro-optics, millimeter wave radar, image and signal processing, hi-g components, advanced materials, electronic packaging, and large system integration. LMMFC-O designs, develops, and builds advanced combat systems, including ground-and air-launched tactical missiles, ground-launched air and missile defense systems, airborne fire control and situational awareness systems, and air-launched strike weapon systems, including smart munitions and penetrators. Its primary facilities, shown in Figure 2.2, include a major research and production facility in Orlando, Florida, with satellite production centers in Ocala, Florida (printed circuit cards), and Troy, Alabama (missile production). Lockheed Martin has designated, as Centers of Excellence, the Orlando facility for smart munitions, and the Ocala facility for electro-optical and electro-mechanical production and assembly.

Orlando, Florida



Sand Lake Road Facility

- 3700 people
- 2.2 million square feet
- Research and development
- Systems and operation analysis
- Product engineering
- Laboratory testing and prototyping
- Manufacturing
- Program management

Ocala, Florida

Electronics Center of Excellence

- 490 people
- 480,000 square feet
- Electronic systems assembly, PWB, ECA, CCA, flex/cable harness, power supplies

Figure 2.2 - Lockheed Martin Missiles and Fire Control Facilities

Missiles and Fire Control Orlando has significant component obsolescence management expertise with a current group of more than thirty Components Engineers. Each of these parts specialists is well versed in obsolescence analysis and they have the necessary combination of expertise, tools, and industry contacts to provide fast, complete solutions. LMMFC-O has developed tools in the area of obsolescence as well.

LMMFC-O also created and maintained several Intra-Company Working Agreements (IWTAs) that provided a scope of effort, centralized program management, and funding to several other Lockheed Martin sites. Lockheed Martin Missiles and Fire Control – Dallas (LMMFC-D), which started the program as Lockheed Martin Vought Systems (LMVS), and Lockheed Martin Maritime Systems and Sensors (MS2), which started out as Lockheed Martin Naval Electronics Sensor Systems (LMNE&SS), both participated in evaluating the ACME/PO tools and performing pilot evaluations. Two Lockheed Martin Aeronautics Systems facilities in Ft. Worth and Marietta (LMAS-Ft. Worth) and LMAS-Marietta) respectively participated in two of the pilot evaluations by providing cost sharing, data, and manpower.

2.2.2 BAE Systems Controls

BAE Systems Controls (BAE) (formerly Lockheed Martin Control Systems) was sold by Lockheed Martin to BAE Systems in mid-2000 and was responsible for evaluating the ACME/PO tools and performing pilot evaluations. BAE SYSTEMS Controls is a supplier of Electronic Digital Fly-by-Wire Flight controls, Jet Engine Controls, and Power subsystems. Controls was brought into the program for its emerging expertise in using Commercial Off The Shelf (COTS) technologies in military/avionic environments. With the shorter product lifecycles of commercial electronics, Controls was developing designs with improved obsolescence tolerance. Funding from POMTT helped support completion of these developments as the tools developed under PO and ACME programs were to be evaluated for use by BAE.

In addition to the evaluation of tools, BAE SYSTEMS Controls' scope was to develop design practices, creating designs using commercial technologies that were tolerant to part obsolescence. In support of that, BAE SYSTEMS Controls was to perform a study addressing the reliability of plastic encapsulated microcircuits (PEM). This data was provided in support of the development of Physics of Failure (PoF) models, a venture started by Georgia Tech and Northrop Grumman.

Section 3

Existing DMS Impact and Needs Assessment

This section defines the needs for DMS management for defense system developers such as Lockheed Martin and BAE as well as for the defense agencies. It looks at the issues from a total system perspective (part to final assembly), processes, tool providers, and case histories.

3.1 Obsolescence Impact on the Defense Industry

The increasing life span of current and future weapon systems, the fast-paced advances in commercial electronic technologies, and the decline in availability of military electronics are the primary reasons for increasing obsolescence that affects military weapon systems. In the 1970s, military requirements drove nearly all cutting-edge electronics research and development, and the military purchased about 35 percent of the industry's output of semiconductor components. By 1984, the military's purchasing had decreased to only 7 percent of the total domestic semiconductor output. However, in spite of the reduced market share, the military's business was still desired in the commercial marketplace because the military purchased and established requirements for the most advanced and profitable microcircuits. In the 1980's, a move to redesign military acquisition processes was emerging to capitalize on rapid developments in commercial electronics and to reduce associated costs from the associated testing and qualification. By the 1990s, the commercial electronics base and the telecommunications industry (which was rapidly becoming a major user of commercial electronics) were expanding exponentially along with their buying power.

As a result, the military's share of electronic component purchases is now estimated to be less than 1 percent, and the electronics market has become increasingly uninterested in meeting the military's needs due to their (relatively) low procurement volumes. While the military's IC supply base eroded, a reduction in weapon system development funding, and the increasing cost of new systems was forcing the extension of systems well beyond their intended service life. As a result, the U.S. Army's current roster of tanks and fighting vehicles is expected to be active until 2030, the U.S. Air Force expects to continue flying the B-52 bomber fleet until 2050 and, although not a specific military system, NASA has extended their 20-year old defense supporting space shuttles to fly 30 years beyond their intended life until 2010.

As a result of these changes in the defense industry, component replacement is often no longer a viable option. Many components are simply no longer available, or at least not available in the same voltages or packaging, and those that remain are not applicable in cost, performance, or reliability with the products now routinely available in the commercial arena. The use of components built to military specifications (Mil Spec) originally was driven by the need to deliver reliable weapon systems. Their lifecycle (typically 10-20 years) corresponded with the anticipated lifecycle of the systems in which they were installed where their enhanced durability and long lifecycle offset their higher initial cost.

The causes of obsolescence can be summarized by focusing on a few areas. Some causes are supplier related (source changes, source depletions, loss of manufacturer influence, etc.), and some are design related (changes in design cycles, a loss of capability to produce an item/lost the recipe). Other reasons are consumer related (distributed inventory needs such as multiple programs being supported across a wide geographical, or political area). A final area concerns military program funding limitations where the solution is clearly identified, but not achievable due to a lack of funding by the customer or the OEM. Funds normally designated for research and development of new technologies and products must now be used to extend the life of existing systems. This potentially establishes a downward cycling trend of fewer funds and fewer new systems. As the cost of new systems continually increases, it results in a lower quantity of new systems that can replace aging systems. Probably the greatest cause of obsolescence, however, is due to the shorter lifecycles of commercial parts. Moore's Law states that the capacities of memory ICs will double every 24 months. That has actually accelerated to where it now doubles approximately every 18 months. As a result, the rate of obsolescence has been steadily increasing over the last 20 years.

3.2 <u>Obsolescence Sensitivity By Item Type</u>

The availability and lifecycle of an item will differ depending on what the item is. This level of obsolescence sensitivity will range from a short lifecycle (high sensitivity) for active electronic parts to a low sensitivity (long lifecycle) for mechanical parts and design standards. Figure 3.1 (below) shows the relative sensitivity of different commodities to obsolescence and their typical lifecycle expectancy. The Figure also illustrates how limited resources, such as the funding and manpower available to proactively monitor program parts, should be spent where the greatest need is. However, regardless of what the sensitivity is or how proactive the approach, the appearance of just one unexpected obsolete item can effectively stop a production line or remove an active weapon system from the military's arsenal.

Obsolescence Impacts

COMMODITY	TYPICAL LIFECYCLE	OBSOLESCENCE SENSITIVITY
• Electronic Parts		High
Memory & Microprocessors	9-24 Months	
• Commercial Software	2-10 Years	
• Electromechanical Parts (connectors, relays, solenoids, magnetics, etc.)	3-15 Years	
• Technologies & Processes	10-30 Years	
TTL Technology	31 Years	
ABT Technology	11 Years	
• Materials	5-20 Years	
• Program Specifications	3-30 Years	
• Mechanical Parts	15-30 Years	
• Standards	10-45 Years	Low

Area 1 -- **Figure 3.1 - Obsolescence Sensitivity by Commodity**

3.2.1 Actives - Electronic and Electrical

Electronic (Active) components such as microprocessors, dynamic and static memory, peripherals, ASICS, and even basic logic chips are the most sensitive since their demand is highest and they are undergoing constant improvement. They are constantly increasing in speed, processing power, and memory size. Investment in commercial electronics is increasing the development of new designs and these quickly push out and obsolete old designs. The technologies used to create the parts (TTL, CMOS, Bipolar, etc.), the equipment used to produce increasingly smaller designs (5 µm, 2.5 µm, and sub-micron), and the voltages applied to run them (5V, 3.3V, and lower) are changing at an increasing rate.

Since ASICS are typically designed for a specific application they are unique by design. This makes them extremely sensitive to changes in user needs.

3.2.2 Passives – Resistors and Capacitors

Passive devices (capacitors, resistors) are not as sensitive as active devices, but can also be affected by changes in technology, suppliers, and the materials used to fabricate them. A potential reduction in the availability of tantalum impacted the chip capacitor industry a few years ago and threatened to reduce the availability of hundreds of parts from many manufacturers.

3.2.3 Electromechanical, Electromagnetic, and Interconnect Components

Electromechanical, electromagnetic (solenoids, transformers, etc.), and interconnect components (connectors, terminals, etc.) are also affected by obsolescence but their sensitivity drops off exponentially. New designs in this area are historically adopted at a slower pace. However, the increased miniaturization of commercial products such as the use of Micro-Electronic Modules (MEMS) continues to foster development of newer and more unique designs that have an increasing similarity to microcircuits and ASICs. These will be inherently more susceptible to obsolescence as they gain more widespread use.

3.2.4 Mechanical

Mechanical devices typically face obsolescence on a slow pace as parts that were designed in the 1930s and 40s still being produced by multiple sources. The primary obsolescence influences on these types of parts are changes in suppliers from buyouts, suppliers going out of business due to a lack of demand, or shifting of supply to cheaper offshore manufacturers. However, material unavailability can affect these items as well, since newer and more exotic materials (such as titanium and multi-phased alloys) are used to replace alloy and stainless steel. For example, a few years ago, a major program in production at Lockheed Martin Corporation (LMC) was impacted by the obsolescence of a high strength bolt. This was due to the drop in manufacturers who were willing to work with a proven material (H-11 steel) that had a high tensile strength but was brittle in the as-worked condition and, therefore, very difficult to work.

3.2.5 Optics

Optics are typically not obsolescence sensitive because, although they are manufactured unique to each application, manufacturers are fairly numerous and the technology appropriate to molding and grinding lenses is fairly well founded. However, changes in their component materials (silicon, sapphire, etc.) and specialty coatings can affect their availability, especially in the near gem-like materials.

3.2.6 Materials

The inability of a manufacturer to obtain raw materials can also result in obsolescence. Material and chemical obsolescence is relatively slow, but the potential impact is much greater. The purchase of bulk materials (metals, solvents, adhesives, compounds, paints, cleaners, plastics, etc.) and chemicals by OEMs is such that these items are used in many applications, typically on a large majority of programs. Therefore, the loss of one key material can cause many programs to scramble for solutions. One such case concerns the availability of domestically-produced, military-grade, smokeless black powder. Although widely used throughout the Army, Navy and Marines, by 2002 there was only one domestic supplier of smokeless powder in the U.S. Foreign suppliers exist but their use may not be viable in a state of war. Work is currently being done by several military and industrial groups to develop an alternate supplier.

In another example Chip Express, who manufactures fast-turn prototypes and production ASICs, announced that they would discontinue 0.8 µm devices in their QYH product family due to the inability to obtain raw material. Three programs (two of which were in production at the time) were potentially impacted: Comanche, LANTIRN, and TADS/PNVS. Chip Express was eventually forced to announce an End-of-Life for all 0.8 µm devices in a particular product family.

A third example was in 1997 when prices for tantalum capacitors were at all-time lows and capacitor manufacturers were keeping production capacity level because profits were low. The majority of all tantalum produced is used in the production of tantalum capacitors. At the same time, however, OEMs were designing greater quantities of tantalum chip capacitors into new products. Due to the larger demand, capacitor prices started to rise in 1998 and, consequently, inventories of tantalum capacitors fell to very low levels. The media then began to publicize the tight supplies of parts and their increasing prices which resulted in a perceived decrease in availability and precipitated a scramble for both the raw material and tantalum capacitors across the supply chain. Speculators entered the marketplace and began driving the prices of raw material even higher. Some speculators also bought and sold out-dated tantalum capacitors, tantalum scrap, and tantalum ore. The market finally stabilized in 2000-2001 as investors left the market and inventories were resupplied. This shows that sometimes a perceived shortage can influence factors and lead to obsolescence.

3.2.7 Assemblies

Like optics, OEM assemblies are typically insensitive to obsolescence since they are manufactured from component parts and are unique to each application. However, purchased assemblies, such as COTS computer processing boards, and products purchased as complete assemblies (black boxes), such as displays and Inertial Measurement Units (IMUs), are susceptible to obsolescence. These types of items are normally designed to perform a specific function by a single manufacturer and are often proprietary in design. Changes to the internal configuration of the product as it is upgraded can make it obsolete for systems, especially if the system relies on a specific capability unique to one version of the design. Changes in the status of the manufacturer can foster obsolescence since many of these are produced by smaller companies that are often the object of acquisition.

3.2.8 Software

Interestingly enough, obsolescence in software is a generally accepted practice. Commercial software program developers provide regular version upgrades and users must constantly purchase new versions regardless of their need. If they do not upgrade within one or two versions they run the risk of losing their data’s upward compatibility. OEM-developed proprietary software is also an area where obsolescence is relatively quickly felt. Commercial software development tools are typically revised at a rate of once every 8-12 months, and can affect written and compiled software code when it is revised for a system modification.

Software standards are somewhat less susceptible to obsolescence and, although newer languages have been developed that can often do the same job of an earlier language, the earlier language is often more efficient. This artificially supports and lengthens a language's lifecycle. For example, FORTRAN and COBOL programs from the 60s, 70s, and 80s are still in use 40 years after development due to the robustness of the language, availability of code, experience of programmers, and the cost of recoding programs into a new language.

A Software Migration Study for a United Kingdom (UK) Ministry of Defense project defined the leading drivers of software obsolescence. Their list included the following:

- Size and complexity of software changes
- Spread of software changes within product
- Extent to which testing is automatic
- Volume of development, certification and legal evidence required to conform with prior and current standards
- Domain experience, availability, and cost
- Existing product experience, availability, and cost
- Development environment experience, availability, and cost
- Documentation
- Testing tools
- Language(s)
- Scale and probability of developer environment hardware changes (due to failure and new software functionality requirements)
- Development environment tool licenses - availability and cost

Software obsolescence even affects the obsolescence solutions industry. TacTech, a leading obsolescence monitoring tool from i2 Technologies, announced that they were discontinuing their AIM-MAX product and were replacing it with a newer tool called TACTRAC. The price for the new tool was also higher, primarily because of increased capabilities.

3.3 Commercial Technology Insertion

The increasing use of commercial technology is intended to provide greater capabilities to military systems, at a more affordable cost. New ICs designed for commercial applications have the benefit of being produced in greater quantities than their mil-spec predecessors and these larger quantities provide more reliable parts. Production consistency (and reliability) is primarily dependent on the length of a production run.

However, the limited environments in which commercial parts are being designed can offset this greater reliability. The large majority of commercial integrated circuits are designed for use in cell phones, video games, other consumer electronics, and telecommunication networks. These products never see the temperature, shock, and vibration extremes normally specified for military products. The closest applications require industrial temperature range rated ICs in applications such as automotive where under-hood temperatures can reach 105°C. This has forced military designers to come up with solutions to address these issues. Two approaches are most commonly used: Cocooning and Uprating.

Cocooning is the method used to take environmentally sensitive devices and isolate them in conditioned, or at least environmentally protected, surroundings to cushion them from temperature, vibration, and shock extremes. Solutions range from something as simple as a daughter or mezzanine board that is mounted on and above a main electronics assembly, to an environmentally controlled enclosure. Sometimes this is combined with additional design or component redundancy to limit the risk due to part failure.

Uprating is the application of performing additional testing, after the parts are sold to a customer, to determine the actual limits of operation in a specific application. Manufacturers do not condone using their products outside of their specified limits and this increases the risk associated with using commercial parts (manufacturers are concerned with the potential liability resulting from a customer using their parts in an application that was not designed for). Additional risk must also be assumed since IC manufacturers may change their processes and designs at any time, and often do for performance enhancements, product fixes, and upgrade improvements. Therefore, users must institute a manual screening process to de-cap or de-pot commercial and plastic ICs in order to visually examine microcircuit die and identify any changes in their design or production. If changes are identified, then additional testing is often performed to see if the new design works as needed.

Unfortunately, commercialization also has the potential to increase a program's risk as COTS subsystems (converters, processor CCAs, etc.) become less costly and more capable. Weapon system developers can also lose expertise, understanding, and involvement with the technical baseline of the design as the quantity of commercial COTS products used in a system increases. Many programs increasingly rely upon and utilize commercial products in order to keep pace with new technology. This may sometimes be detrimental to the program as the number of changes in the commercial world outpaces the complexity of design and availability of funding in the military world.

New products being developed in the commercial sector, however, can provide enhanced safety in airborne systems as the technologies used to produce them continue to mature in performance and reliability. The use of COTS components in airborne systems does raise a number of issues (such as critical applications) where screening and testing levels may not be attainable by COTS components. This issue is being addressed by the Government Electronics Industry Association's (GEIA) Approved Qualified Electronic Components program (AQEC). The AQEC program is in the process of being established by the GEIA's Avionics Process Management Committee (APMC) to help provide the aerospace and defense industry with active parts (ICs, microcircuits, etc.) that have undergone additional qualification testing. Parts that meet the AQEC requirements are designed and tested to verify operation at wider temperature ranges (military and space) with potentially lower or qualified failure rates. Currently, only Texas Instruments (TI) is producing parts that are expected to meet this spec, but talks are underway with several other IC manufacturers and their plans have not yet been finalized.

Aerospace and defense suppliers are particularly interested in this work since they need qualified parts to meet performance, environmental, and qualification requirements, especially in satellite and missile rated parts. Historically, qualification costs can add a tremendous burden (often a 30-40% cost increase) to their potential usage. The goal of the program is to accept a modest increase due to this testing. However, test equipment, fixtures, software, and device fallout during testing can increase the prices of these parts, and there is a potential to see prices comparable with those of DESC and MIL-STD devices, especially if demand is small. It is also possible that prices may be even higher than previous mil-spec parts, depending on the level of demand and number of manufacturers participating. Currently, only Texas Instruments has introduced a product line called the QML Class V for space products. Power management and 5V digital logic devices have already been released with planned expansion into other product families. It remains to be seen if the industry's need is great enough for other manufacturers to enter this market.

3.4 Source Deletions

Manufacturers disappear and drop out of the marketplace for many reasons, including a downturn in the economy or their particular marketplace, poor management, changes in management, loss of expertise or skilled labor, and solicited or unsolicited takeovers and buyouts. All of these options result in the same impact - elimination of a source. This is not usually a cause for concern unless the source is the sole remaining manufacturer of an item.

There are a number of solutions to this problem, including development of additional sources, reverse engineering by a qualified manufacturer, and evaluation of similar, but not always identical, and components for use in the assembly. Each of these has a level of cost that must be understood in order to identify the most viable approach.

3.5 Source Design Changes

Even if a manufacturer does not go out of business, a part may become obsolete due to changes in its design or manufacturing process. Many times design or production process changes, even though often intended to continue "form, fit, and functionally" equivalency, can result in changes to documented and undocumented parameters that may have been relied upon in an original design. Changes in materials can also make a new design part incompatible with an existing application.

Sometimes impacts occur even though the manufacturer has stated a commitment to remain as a continuing source. For example, Microsemi obsoleted a part in spite of their Corporate Mission Statement to the contrary. Microsemi's Santa Anna marketing division stated that "although it is one of Microsemi's Mission Statements that they will not obsolete a part, they feel compelled to do so with this one". The part design was transferred to other manufacturing sites, but there was no improvement in yield. Therefore, although the delivered parts met all electrical specifications and worked correctly in existing applications, the supplier obsoleted their part due to difficulties in manufacturing and production (i.e. yield).

Often when suppliers make improvements to their parts, this information is never passed to the users (unless there is a significant relationship between the manufacturer and the user). The user's primary recourse is to perform internal die inspections, document the die characteristics, and watch for any changes. When changes are detected, the parts must be tested for compatibility and possible changes in performances. There may also be additional system re-qualification impacts that must be accommodated. For example, when a supplier changes their manufacturing location (or tooling), the result can be very much like having a part change. Danaher, an instrument bearing manufacturer who provides matched bearing sets for Lockheed Martin, began a process to improve their retainer locking mechanism. The impact of this change was an unannounced reduction in supply with evaluation samples available within a three- to four-week time. Since Danaher was the only supplier for this item, their improvements resulted in an obsolescence issue for a production program. In this instance, the program had some lead-time available in their production plan that allowed them to perform a simplified test of the new design and, thereby reduced the impact of the change. However, complex electronic devices rarely have little impact and obsolescence events resulting from design changes are much more common.

3.6 Manufacturer's Parts (Vendor Part Numbers)

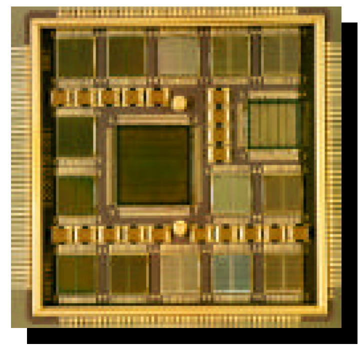
Typically, manufacturers do not recognize parts produced by their competitors and will not provide identical or even similar parts (even if available) unless identified by their own part number. Since the part numbers are unique to each manufacturer, this effectively makes them single sourced and extremely susceptible to obsolescence.

Previously, military specifications provided the performance and reliability parameters for a given part, and manufacturers would qualify their part to the mil-spec. These mil-specs typically provided a single, common part number and multiple sources of supply. The Defense Logistics Agency's (DLA) Defense Supply Center Columbus (DSCC) has developed Standard Microcircuit Drawings (SMDs) and Qualified Manufacturer Lists (QML) to help reduce the impact from the lack of military specifications. OEMs can also protect themselves from this type of obsolescence by documenting their own requirements, but must also assume the costs involved.

3.7 Historical Case Studies

One of the earliest programs at Lockheed Martin to establish a continuous obsolescence management process was the LANTIRN program which began development in the early 1980s. This system consists of externally mounted targeting and navigation pods and is used on the F-14, F-15, and F-16 fighters. They were densely filled with electronics and, when designed, used the latest cutting edge integrated circuits designed using Fairchild Advanced Shottky Technology (FAST). The project was scheduled to have a 20-30 year production run so Lockheed Martin was contracted to perform obsolescence management on all parts used in the system. As a result, the vast majority (greater than 80%) of the parts that went obsolete over the last 20 years were replaced with Form, Fit, and Functionally Interchangeable (F^3I) replacements. Two typical obsolescence cases are depicted below:

Case Study # 1 - Harris ASICs



Background

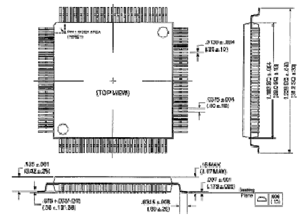
- Designed during1984
- Became obsolete in 1994
- No product knowledge retained at Harris

Options

1. Redesign subsystem - Expensive and risky
2. Locate available stock – None available
3. Locate die and repackage

Resolution

- Located wafers in Malaysia
- Wafers were cut and probed at OEM's cost
- Obtained test tapes/documentation, burn-in boards, test cards, and test head at no cost due to established relationship with supplier
- Repackaged die



<u>Case Study # 2</u> - ZR33891JB-15: Digital Filter Processor

<u>Background</u>

- Obsoleted by Zoran in 1994

<u>Options</u>

1. Replace with Harris HSP43891 – Package not available
2. Replace with Logic Devices LF43891 – Errors in die
3. Replace with new ASIC – 40K gates, 10 man-months effort, est. $150K NRE
4. Located existing stock – available @ $348/device
5. Die buy out and repackage – Not available
6. Buy Harris die and develop package

<u>Resolution</u>

- Procured Harris die
- Kyocera package redesigned to accommodate Harris die $150K NRE

These two cases illustrate what was happening in the early 1990s as military programs designed using military specifications were being forced to use more and more commercial and industrial ICs in order to meet performance requirements. The LANTIRN program was a completely new design when it began production in the late 1980s. As the program, and other military programs, progressed through the 1990s, the rate of obsolescence increased to where, by the year 2000, even potential replacement microprocessors and memory chips were going obsolete after only 12-18 months in the marketplace.

3.8 <u>Design Trends</u>

A change in design approaches has a strong impact on the availability of parts since these changes are often made and felt industry-wide. Luckily, most trends are gradually introduced (often over a number of years) and their impact can be minimized through introduction of the new technology in new designs. An example of this is where the semiconductor industry had established $\pm$5V as the standard operating current for devices over the last 20 years. New changes in technology are now driving $\pm$3V as the new standard, and parts are being designed with even lower operating voltages. At Lockheed Martin, these changes are typically phased in on a program-by-program basis as new system designs are instituted, electrical parameters are established, and preferred components are selected.

3.9 User Needs

The needs and capabilities of the military and manufacturing industries will be addressed in the following sections.

3.9.1 Military

Military services requirements are characterized by a long system life and mission driven necessities with difficult and sometimes impossible system, or subsystem replacement; whereas, commercial and industrial requirements are generally characterized by planned short system lives and more performance driven necessities with easily replaceable elements.

One example of proactive obsolescence management was the work performed by the U.S. Air Force B-2 Bomber Program Office. Donna Dillahunty, who worked at the B-2 Logistics Management Office, who noted that they first learned a part was obsolete when spares orders were returned from the vendor as no-bids. In an attempt to get their hands around the problem they gathered engineering and cataloging information and entered it into a database. This data was then networked into a repository of obsolete parts information gathered from almost every IC vendor in the world, along with lists of alternate parts that have been used by other weapon systems. In essence, they developed their own, labor-intensive data management system that included obsolescence as a primary factor.

This demonstrates that there are no easy or comprehensive fixes to the obsolescence problem. Efforts are labor intensive; they must be based on a sound business plans, and cannot always be managed by simply placing the requirement onto the prime contractor. The B-2 process included tools such as TacTech to help define the obsolescence risk of each subsystem and line replaceable unit (LRU).

3.9.1.1 Sustainment

NASA is a victim of its own success in keeping the Space Shuttle fleet operational. The shuttles are so old that NASA and its contractors have to use extreme measures to find substitutes. Originally, the shuttles had a planned design lifetime of 10 years with little planning for upgrades or refurbishment. They are now expected to fly until 2010, and NASA is conducting research to see if their retirement date can be pushed back to even 2020.

To keep the shuttles flying, NASA began searching the Internet to find replacement parts for electronic gear that was designed in the 60s, and built and installed in the 70s. Acquisitions include outdated computer chips, circuit boards, and eight-inch floppy-disk drives. NASA also bought outdated medical equipment to scavenge Intel 8086 chips for booster testing. Future NASA plans call for an automated test system, with all new hardware and software; however, this depends on congressional funding and government leadership.

3.9.1.2 Modernization Rather than Maintenance

On the PATRIOT missile defense system, the Army wanted to buy modernized versions of the system's "end items" rather than overhauling all of the older structures of the legacy system. Raytheon pursued and internally funded an initiative dubbed PATRIOT-Light to make the missile defense system lighter, more deployable, and more enticing to upgrade dollars.

This is an approach that has been used for many years. Modernizing a system through upgrades has proven to be a tried and true way of continually increasing a system's performance and usable life, while pushing out the obsolescence dates of its components. However, with funding for new systems reduced and increasing system development costs, it is becoming more and more difficult to modernize through upgrades. Fewer upgrades are being requested, and those few that are being pursued must also leverage industry investment. An example of this is the Air Force's new targeting system, the Sniper Advanced Targeting Pod (ATP), which was developed at Lockheed Martin's expense and is now entering production.

However, other program offices that do not have the funding or management support to find replacement alternatives are faced with the prospect of maintaining their systems well beyond their planned life.

3.9.1.3 ALC, Depot, and SPO Needs

The military services' needs begin primarily after product acceptance and extend all the way through the lifetime support of the system. Military systems have extended lifecycles and their needs are tailored more to system usage and maintenance than most commercial products. Programs typically rely on OEM-managed and government-managed depots to perform these functions. The Air Forces' Air Logistics Centers (ALC's) also need obsolescence management tools, primarily for application in the support of multiple programs, equipment stocks, and spares. The most critical depot issues are a result of these aging systems, including:

- Limited or unavailable supply
- OEM not existing or not supporting
- Urgent need
- Long procurement cycles

When faced with these issues, depots must develop their own production capabilities and often must manufacture their own supply inventories due to the lack of availability of the original products. There is currently little information integration between these support centers (each one being focused on a specific area of expertise) and what work is being done often runs into problems. Unfortunately, one solution (EDS's contract with the U.S. Navy to provide a centralized plan for the Navy's own Intranet), has been slowed due to problems with the contractor. There is a clear need for the NMCI system, and users are expected to gain significant benefits, especially from the sharing of information.

System Program Offices (SPOs) are different from depots since they participate in establishing the original system requirements and also have a say in product development. They also need obsolescence management tools but are more interested in early identification of potential problem issues, greater system operational availability time, and wide system usage in order to gain the greatest benefit. Production planning and procurement scheduling would benefit from a tool that provides obsolescence assessments for cost, schedule, and planning functions early in the program's life.

3.9.1.4 Air Force Trends and Future Needs

The future of the Air Force has been outlined in a number of areas such as a greater emphasis on space operations and applications. Also, Unmanned Aerial Vehicles (UAV's) are becoming more and more applicable as capabilities increase and size decreases. However, these and other trend areas (Advanced modeling and virtual testing, partnering with commercial industry, and faster force projection) will still depend on commercial electronics, and therefore obsolescence will continue to be a factor.

Tools, technologies, and processes developed today will impact the way future systems are designed as they become ingrained in the design process. System level design, although currently extremely expensive for a complex system such as a fighter aircraft, should follow the trend of electronic and mechanical modeling systems and become the norm. SLDL and Rosetta have the potential of providing the underlying technology to bring the products of the currently discrete development and analysis tools such as PRO-E, Mentor, and MATLAB together to share data more efficiently and even interoperate. This is absolutely critical if true system level modeling is to become viable.

Advanced, increased capability versions of currently available and newly-developed obsolescence tools will continue to be developed. Tool and Technology solution development however, will need to be fostered as it was under EPOI, or the scope of the problem will increase. If not, then new solutions will emerge only when commercial vendors are able to make a business case that supports developing a product.

3.9.1.5 Reduced Cost of Ownership

Operations, maintenance, and support costs typically run two to three times as much as the initial development costs. These costs consist of direct costs that apply to the operations and maintenance of specific weapon systems and indirect costs resulting from the support of the overall infrastructure. Cost elements typically include:

- Operation and maintenance personnel
- Propellant/energy consumption
- Repair parts/spares
- Training munitions and expendables
- Contractor and contractor logistics support
- Intermediate and depot level maintenance

- Sustainment support such as support equipment, modification kits, software maintenance, simulators
- Indirect support for personnel and installations

Actual cost trends continue to show O&S cost increases for delivered systems. It has been reported that the predominant root cause of these cost increases is age and obsolescence. Almost two-thirds of the component root causes for aircraft repair cost increases were directly tied to aging systems (aging and obsolescence) and obsolescence issues predominated in systems with higher concentrations of avionics.

Maintenance studies need to be focused on individual pieces of equipment in order to allow for the collection of root failure cause data. The BAE Ball Grid Array (BGA) modeling study that used Georgia Tech's (GT) Physics-of-Failure based modeling illustrated that, although maintenance records and fault identification software identified suspect boards and components, actual physical analysis was still required to identify the micro-cracks observed in PEM solder balls. Actual validation of GT's reliability models resulted in, and accurately predicted, the actual failures. Serialization of system components and more specific Built-In-Test (BIT) software programs can be used to provide more detailed engineering descriptions for trend analysis.

Historically, the sharing of data between the Government agencies and industry has been very difficult. However, teaming to provide investigative approaches as shown in the POMTT pilots has proven to provide information that would not have been otherwise available. Initiatives like EPOI provide the impetus for this type of collaboration.

3.9.2 Lockheed Martin Corporation

Lockheed Martin has a requirement to meet their customer's needs, and the effect of obsolescence on system requirements such as availability and performance, must be considered. Although it is the leader in design and production of military weapons systems, LMC is focused on continuous improvement.

As mentioned in the previous sections, the company has been working on solutions for obsolescence for almost 20 years. LMC became involved in POMTT because it recognized the changes that were taking place in the commercial and defense industry, the resulting increased cost impact on their products, and their impact to the company's ability to remain competitive. Therefore, Lockheed Martin chose to evaluate their capabilities and needs to ensure they could meet those of their customers.

3.9.2.1 White Papers

A Phase I analysis in the early 1980s found that, although obsolescence's greatest impact is in the IC and semiconductor industry, it can strike any other commodity area and that the defense aerospace industry, including Lockheed Martin, was not doing an effective job of managing obsolescence.

A follow-up Phase II analysis showed that the defense market had a decreasing influence on the IC market and could not prevent or forestall obsolescence.

Lockheed Martin developed a Parts Obsolescence white paper in 1993 that recognized the developing problem. Two major categories of obsolescence were identified:

- Discontinuance due to market sales factors
- Discontinuance due to manufacturer closures, mergers, and acquisitions

Based on these assumptions, actions were recommended. A multi-functioned obsolescence review team would be established and a technology assessment of the associated tools, procedures, best practices, and lessons learned should be performed. Commodity Teams were established to perform manufacturer surveys, obtain external support data services, and identify a preferred rating system.

3.9.2.2 Existing Processes, Capabilities, and Tools

Lockheed Martin found that existing design tools and standards (such as Mentor and VHDL for design and redesign, database management, reliability assessment, and technology insertion) were not designed or accurate enough to address the obsolescence problem. Therefore, in the mid-1990s a review was performed of LMC-Orlando's current obsolescence tools and management methods, revealing a number of obsolescence solution approaches being used:

- GIDEP alert reviews
- TacTech lifecycle status check
- Evaluation of new technology families and similar devices
- Interface with DSCC
- Periodic review of OEM Internet pages
- Review of Data P.A.L., IC Master, and other technical publications
- Participation in Industry and government committees and conferences
- Regular status reviews of manufacturers and devices on proactive programs
- Periodic visits to manufacturing facilities to discuss obsolescence and observe current capabilities
- Component Obsolescence Management Database (COMAND) and Case History

These were being applied in an as-needed, as-recognized, and as-funded manner on a program-by-program basis.

A subsequent Obsolescence Cost Analysis study in 2002 revealed that only approximately one-third of the programs at Missiles and Fire Control – Orlando were contracted to actively monitor their parts (only one program surveyed all of their parts). A second one-third only had sufficient funding for a limited solution approach (such as monitoring only the most sensitive components such as ICs), and the remaining one-third did not have any funding at all and either did not perform any obsolescence monitoring or relied on their customer for obsolescence notification. An analysis of the programs that were performing obsolescence management revealed four different approach types:

TYPE	***DESCRIPTION***
1.	Active obsolescence management led by components engineers
2.	Obsolescence management through a teaming approach (sometimes led by Product Support)
3.	A reactive type of obsolescence management
4.	Programs with no Lockheed Martin obsolescence management

The programs used to gather this data included:

PROGRAM	***CUSTOMER***	***TYPE***
LANTIRN	Air Force	1
Patriot	Army	1
Sniper ATP XR	Air Force	1
TADS/PNVS	Army	2
AGM-142	Air Force	3
Hellfire/Longbow Missile*	Army	4
Predator	Marine Corps	4
Javelin	Army	4

(* Note – The Hellfire/Longbow program initiated an Obsolescence IPT in 2003 and participated in and used the results from the POMTT program)

The cost analysis also captured the non-recurring costs associated with each type. For each program the labor hours required to work an obsolete part problem were collected using three different methods:

- Surveys filled out by the components engineers who worked on those programs
- Interviews with various program personnel
- Financial reports of funds expended on obsolescence activities

Labor hours were captured to estimate the times spent working but, because of insufficient cost data to determine the impact of additional redesign, and aftermarket and alternate part costs. Industry-estimated cost values from the Defense Microelectronics Activity (DMEA) were also used to calculate the total impact costs. These cost factors provide an average cost of resolving DMSMS problems and were applied to calculate cost avoidances. Additional details concerning the actual costs are included in Section 5.

Obsolescence management is primarily a tool for reducing or avoiding downstream costs, rather than generating immediate savings. However, the challenge can be addressed with a proactive, team-oriented approach based on analyses using tools already available.

Identification of second sources is also a costly issue that affects future obsolescence and is usually not funded by programs until after problems arise. Many development programs barely have enough budget or schedule to complete a design, let alone fund second source development. Most programs that are in early design stages do not have components engineers on staff; however, they are typically tasked with working the issue. This all should be included in, and used to help establish, business plans and detailed business cases that show the Return On Investment (ROI) by having the necessary disciplines on board early during design.

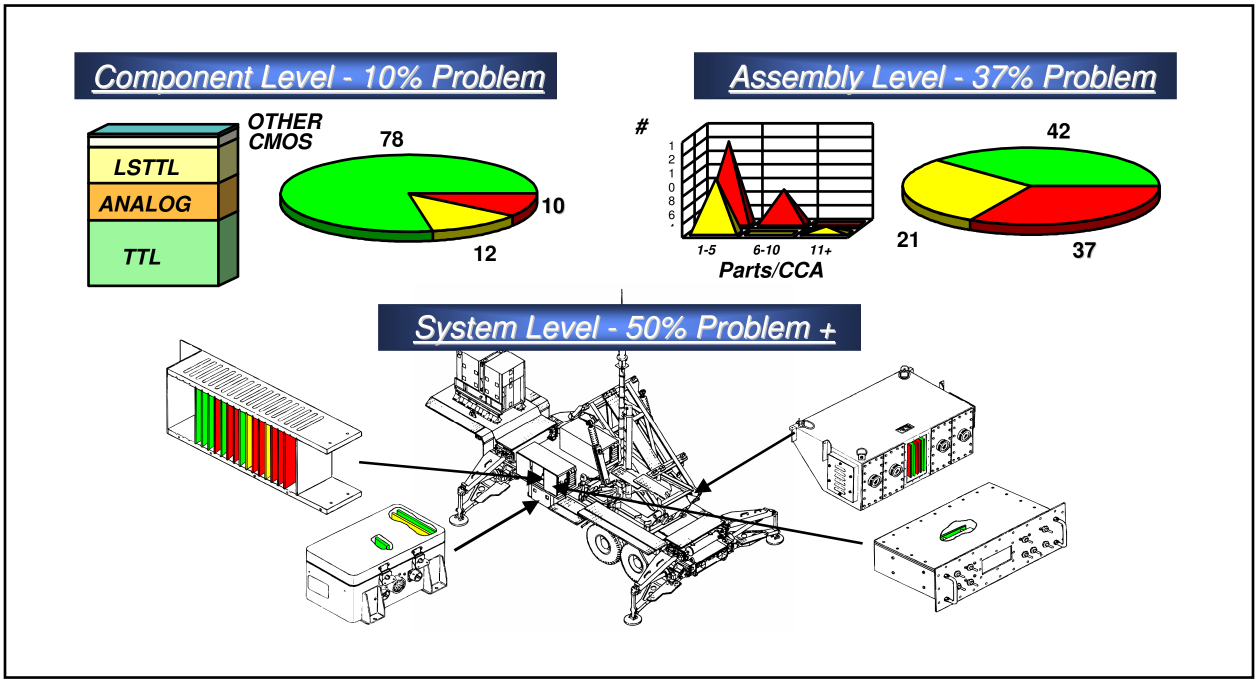
3.9.2.3 Existing Policies, Procedures, and Practices

At the start of the POMTT program, coordination with management and obsolescence personnel began on a number of Lockheed Martin programs, including F/A-22, F-15, JSF, TACMS, MLRS, LOSAT, PAC-3, LANTIRN, TADS/PNVS, and LOCAAS, to review current approaches to obsolescence management and to communicate the need for pilot programs involved in assessing advancements in POM tools. These programs were expected to be the primary source of data on existing obsolescence management practices.

Lockheed Martin's existing obsolescence procedures were also baselined at the beginning of the program. It was revealed that there was little obsolescence management being performed, and most of what was being done was only reactive. Electrical and electronic in-house parts were typically the only parts being monitored, and those only on programs that had foresight and funding.

The LANTIRN Navigation and Targeting Pod program was funded through a separate contract by the Air Force Program Office to perform continuous obsolescence monitoring and analysis. Both Navigation and Targeting Pods were baselined in 1984. They used leadless, ceramic chip carrier packaging and custom package footprints (40 mil centers between pin lands versus a 50 mil center industry standard). The project applied TacTech and manual supplier reviews and established the Components Obsolescence Management Database (COMAND) to track the cases and maintain a solution history.

The PATRIOT missile program performed an assessment of obsolescence and determined that the problem affected approximately 10% of the components, 37% of the assemblies, and 50% of the system (as illustrated in Figure 3.2).



Area 2 -- Figure 3.2 – PATRIOT Program Obsolescence Impact

The TADS/PNVS targeting and night vision system for the AH-64 Apache helicopter also had a mature design and was developed using full military requirements. Their obsolescence approach was handled on a part-by-part basis primarily using part substitution as a solution. This often required re-qualification of the parts and sometimes used a lower quality part screened to a higher level when nothing else was available and approved by the customer. The program had very limited electrical design modeling and consisted of a thru-hole board design approach using TTL and CMOS technology microcircuits.

3.9.2.4 Procedures, Best Practices, and Databases

Throughout Lockheed Martin Corporation there were Policies, Procedures, and Best Practices that existed at some sites that already addressed the problem, but some deficiencies still existed. For example, at the corporate and divisional level, no policies existed that addressed obsolescence. Several internal operating procedures were found, however:

SPI 099	Components and Materials Obsolescence Management (Missiles and Fire Control)
PD–281	Diminishing Manufacturing Sources (Astronautics)

EN 04.04	Controlled Use and Supersession of Obsolete Parts and Materials and Processes (Aeronautics)
COMP-105	Obsolete Parts and Assemblies (Maritime Sensor Systems)
PD-6000-42	F-16 Program Diminishing Manufacturing Sources (Aeronautics)

Additionally several discrete obsolescence databases were found to exist, but these were not integrated and no data was shared other than by word-of-mouth.

Maritime Sensor Systems (Syracuse) Part Obsolescence Database

BAE Systems Controls (Johnson City) Part Obsolescence Database

Aeronautics (Ft. Worth) DMS Database Access

BAE Sanders (Nashua) DMS Notices

Missiles and Fire Control (Orlando) COMAND Database

Finally, a lessons-learned search was performed on the Corporate Lessons-Learned Database that revealed 21 lessons dealing with obsolescence. These covered a variety of topics including GIDEP, TacTech, obsolete parts management for design tools, and component derating. There were no specific part cases or solutions documented in the system.

3.9.3 Missiles and Fire Control – Dallas Process and Tools Baseline

Early in the program Dallas began assessing the baseline parts obsolescence programs within Lockheed Martin Missiles and Fire Control – Dallas. The baseline program for obsolescence assessment was selected - The MLRS M270 Launcher production and engineering services program. Missile programs like TACMS and Extended Range MLRS have had production related obsolescence issues and could have been selected however, there are many reasons in favor of selecting MLRS. MLRS launchers have been in production and service for many years and have undergone extensive obsolescence related modifications, upgrades and mitigation activities. The data from MLRS obsolescence activities is much more extensive than any other program at Lockheed Martin Missiles and Fire Control – Dallas. In fact, the process used on the MLRS launcher has become the baseline for development of the improved processes based on Aspect Development's CSM capability.

Aspect Development used the MLRS Electronic Component Database as a starting point in their definition of the LCM module for their eDesign Lifecycle Management (LCM) module being further developed under the Air Force ManTech program. The baseline MLRS obsolescence tracking capability is based on a Microsoft Access database containing the launcher electronic parts list. This database is linked to the TacTech obsolete parts database to automatically identify, assess and track obsolescence issues. A similar functionality has been incorporated into the Aspect CSM system to automate part obsolescence management for all programs and provide appropriately screened information for the functional departments; i.e., Engineering, Quality, Manufacturing and Materials.

This baseline revealed several needs for process improvement. There is a limited review of concurrent data. This review is currently slow and includes an approval process that is too lengthy. This is primarily due to the manual nature of the process where paper is carried from reviewer to reviewer to approver. Additionally, each department must re-enter the data and this often leads to errors.

There is an inconsistency across multiple programs, little data reuse, much of the data is paper based and not electronic, and most solutions are primarily reactive. Current obsolescence part reviews are handled using either a program specific Access database or TacTech. This manual analysis required continuous reassessment. Typical obsolescence solutions used at M&FC-D were LOT-Buys, Recertification, Reclamation, Substitution, and Emulation.

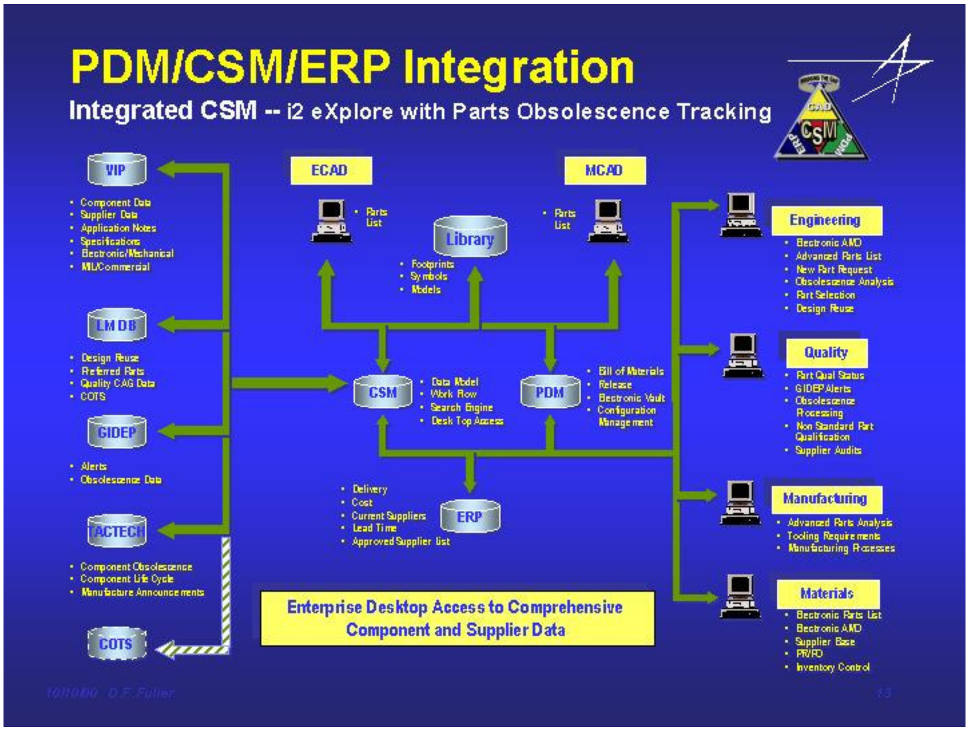


Figure 3.3 – PDM/CSM/ERP Integration

Figure 3.3 above shows the enterprise approach to PDM/CSM data integration. The i2 Technology tool eXplore is the heart of the CSM system. A strategy was proposed to establish a single integrated process using the PDM/CSM structure to support a more proactive obsolescence management approach and concurrent engineering. This approach would facilitate parallel reviews, markups, and approvals. Early and continuous obsolescence assessments and parametric based alternate searches would be supported. If selected this completely electronic capability would also all greater integration between the engineering CAD models/data with Manufacturing. This electronic process would automate requirements such as BOM creation from existing CAD design tools and part reports and assessments. It would also provide a web-based link to external suppliers, sources, and subcontractors. An integrated process would also support the identification of company preferred parts, allow parts to be associated with models and symbols from other systems, facilitate new part requests and parts list creation, and early notice for long-lead procurement, corporate buys, and obsolescence identification. An example of a new-parts request process that shows the obsolescence integration is provided in Figure 3.4 below.

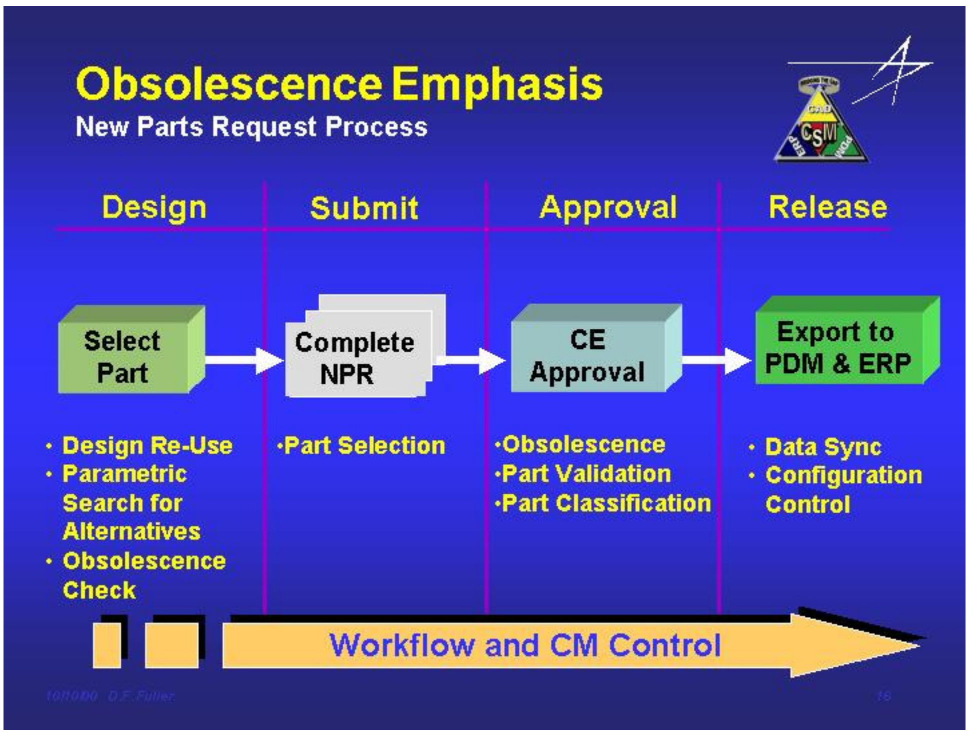


Figure 3.4 – New Parts Request Process

Another reason for better integration is the requirement to establish common processes between the Missiles and Fire Control Dallas, Orlando, and associated facilities (Lufkin, Ocala, Troy, etc.). It also anticipates future vendor and customer integration for data transmission, approvals, and acceptance. An integrated obsolescence process also allows planning for future productions and procurements, while facilitating technology insertions and refreshment.

The Aspect CSM tool has already been implemented in the production process and has successfully completed its initial rollout to the LOSAT program. Training and rollout of CSM to other programs and sites has also begun. It can serve as the basis for newly available and evaluated tools and processes from the ACME/PO program.

Data and reports on prior obsolescence management efforts were collected and reviewed along with plans for future activity at the start of the program. Some of this data included:

- A 1996 MLRS FCS System Impact Analysis, July '96 and Apr. '97
- Electronic Component Obsolescence Assessment of the MLRS M270A1, Dec. '97.
- System Impact Analysis of the Multiple Launch Rocket System (MLRS) Fire Control System (FCS), April '98.
- Statement of Work, Aspect, Phase II CSM Implementation, Lockheed Martin Missiles and Fire Control - Dallas, Ver. 1.9, Jan. '00
- Capital Equipment Acquisition Request, A-1998-C-0049, Component And Supplier Management System, Jan. '98
- Capital Equipment Acquisition Request, A-1999-S-8008, Component And Supplier Management System Phase III, Jan. '00
- Configuration Management Plan for Multiple Launch Rocket System, 4-11200/OR-001, 15 Feb. '93
- FY 94 MLRS PRODUCTION CONTRACT DAAH01-94-C-A005 MLRS Parts Obsolescence Statement-of-Work (SOW)
- Preliminary Obsolescence Management Plan For the M270A1, Draft Feb. 1999
- Dallas continued to collect and review data and reports from prior obsolescence management programs and tools as the program developed. Dallas also examined plans for future efforts. These included:
- TACMS, LOSAT, LOCASS, MLRS, and PAC 3 Obsolescence Program Presentations
- AMCOM DMSMS Case Resolution Guide
- DMEA Resolution Cost Factors for Diminishing Manufacturing Sources and Material Shortages (DMSMS)
- Litton's Electronic DMSMS Roadmap
- i2's eDesign Product Description
- During the current reporting period, Dallas also attended conferences under this program. They presented a number of obsolescence-related papers and presentations at DoD and industry Conferences, as well as at the bi-annual EPOI Workshops.
- Other data and reports collected included:
- DMSMS Conference Proceedings
- Lockheed Martin Missiles and Fire Control - Dallas EDA Tool Suite

- CSM Training Materials (Basic Navigation, Workflow, Non-Production Materials Request (NPMR), New Part Request (NPR), Bill of Materials (BOM), and Component Change Request (CCR))
- Raytheon/i2 LCM Software Requirements Specification

Dallas has worked closely with MLRS and PAC 3 obsolescence management teams and with similar teams in Orlando, Fort Worth and Marietta to collect information on current obsolescence management practices, procedures and costs. For example: the MLRS program indicated that they expended about $3M per year to manage obsolescence just on the M270 launcher. Dallas also received access to the obsolescence database for both the F16 and MLRS programs which provided the initial program plans and estimates for the MLRS obsolescence effort that began in the mid 1990's.

3.9.4 LMC Baseline Summary

Overall, the majority of all sites had the same approach. An indentured list of parts for all the electronics in a system is typically set up in a database. Vendors are monitored by engineering staff particularly when production and procurement activity determines that part availability is eroding. Services like GIDEP and TacTech are used to continually assess part lists and identify new end-of-life announcements and estimate remaining life expectancy. Personnel also participate in DoD DMSMS activities and monitor activities on similar parts by other programs. As appropriate, decisions to redesign, buy extra parts to meet future needs, store parts, reclaim parts from spares or other sources, etc. are made as appropriate for each obsolete part with little coordination with other Lockheed Martin programs or sites.

3.9.5 BAE Systems Controls

BAE SYSTEMS Controls Obsolescence plan incorporates a strategy to minimize obsolescence risk for the life of a program. It encompasses a comprehensive program that starts at program inception and continues until the products are removed from revenue service.

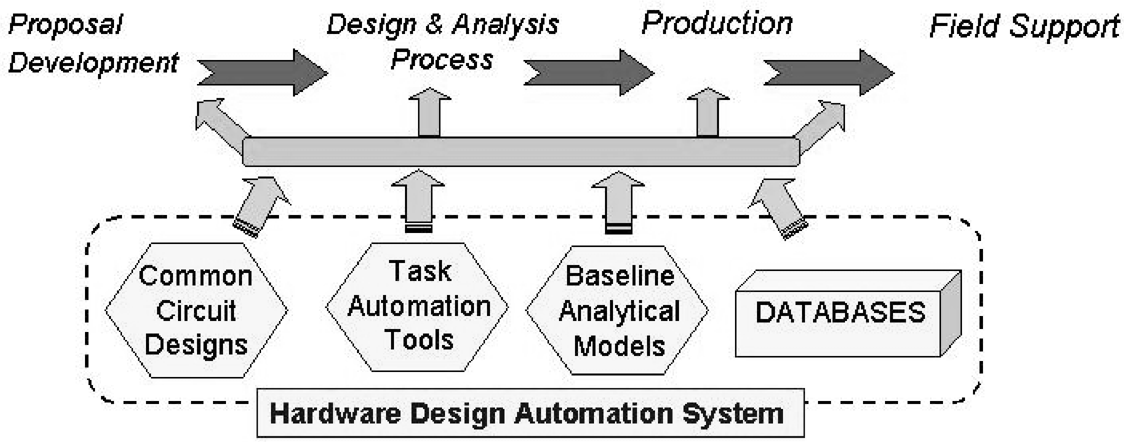


Figure 3.5 – BAE Design process

BAE's existing Obsolescence Management System is comprised of three major areas: Part Selection, Part Monitoring, and Configuration Analysis. The Hardware Design Automation (HDA) system is the focal point for each area. HDA is the collection of preferred components for part selection, component data for part monitoring, and configuration analysis to allow the lowest cost management of designs.

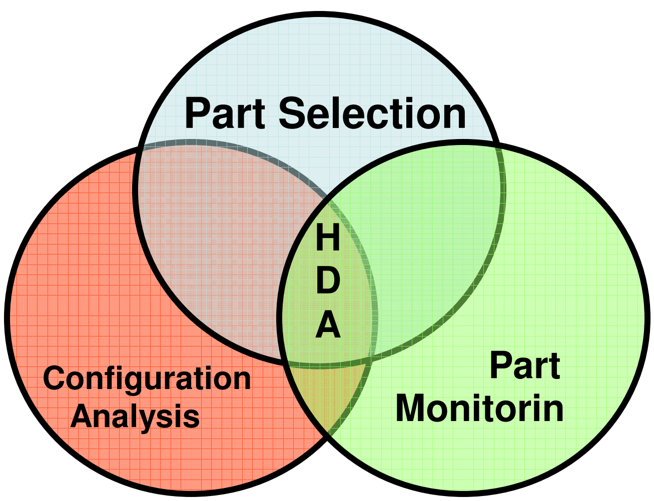


Figure 3.6 - Design for Obsolescence Mitigation Process

Parts Obsolescence Management of a program starts at part selection. The Components Program Lead defines a preferred set of parts for that program selection based on program needs, part availability, part standardization, part cost and part technology. The function defines parts lists for selection of components and design features (architecture) to maximize life of the product and minimize scope and cost of obsolescence change when it occurs. This process drives part selection, partitioning, and packaging features to remove risks out of the design.

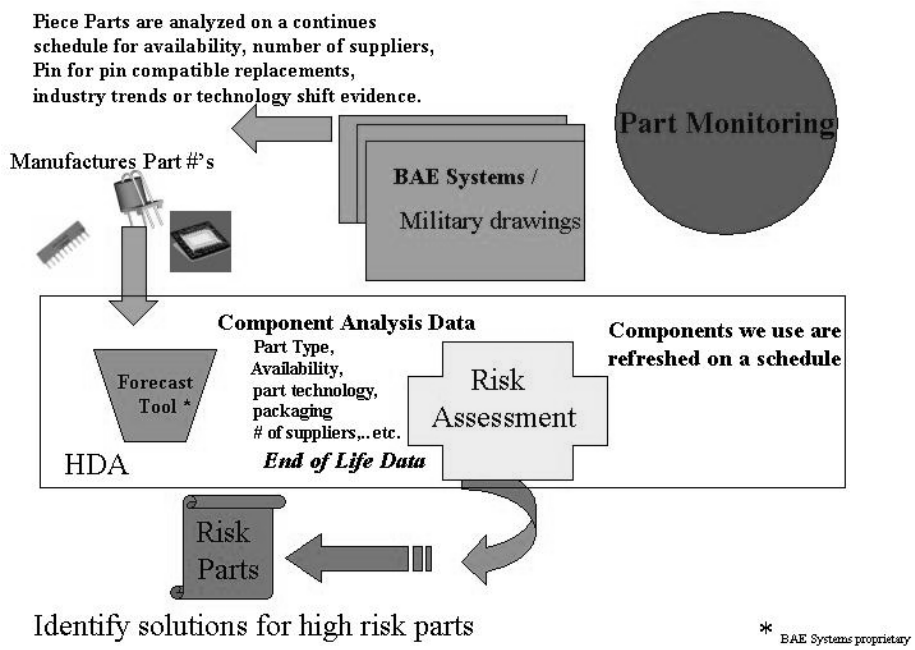


Figure 3.7 - Production Obsolescence Mitigation Process

Also, continuous monitoring of all electrical parts used in Controls Products for component obsolescence helps ensure timely identification of risks and mitigation plans.

3.10 Presentations and Reports

POMTT documented a number of presentations, data, and various reports from prior obsolescence management programs and tools, as well as examined plans for future efforts. These included:

- M&FC-Dallas Obsolescence Program Presentations
- AMCOM's DMSMS (Diminishing Manufacturing Sources and Material Shortages) Case Resolution Guide
- DMEA's Resolution Cost Factors for Diminishing Manufacturing Sources and Material Shortages
- Litton's Electronic DMSMS Roadmap
- i2's eDesign Product Description
- Engine Control Service Center Data Collection TIM (Fort Wayne)
- Aeronautics' Application of the Litton TASC Tool for C5 (Marietta)

Missiles and Fire Control - Dallas hosted an Obsolescence Management Technical Interchange Meeting early in the program to encourage collaboration and participation in the POMTT pilots. In addition to presentations on the POMTT program and all the POMTT tools, LOCAAS, LOSAT, PAC 3, TACMS and MLRS presented their approach to obsolescence management. The Dallas Component Supplier Management (CSM) Seamless Integration Team (SIT) presented a new Product Data Management (PDM), CSM and Enterprise Resource Planning (ERP) systems and demonstrated the use of CSM's obsolescence mitigation tools. Additional presentations and demonstrations on related virtual prototyping, Commercial Off-The-Shelf (COTS) insertion, and plastic encapsulation efforts were shown in their relation to obsolescence mitigation and the POMTT pilots.

3.11 Benefits and Disadvantages of Managing Obsolescence

As with all issues, there are both benefits and disadvantages in managing obsolescence. The next few sections address the effects of obsolescence on costs, productivity, and risks that are encountered by both industry and government.

3.11.1 Changes in Productivity and Return On Investment

Although component solutions may have been applied, most programs won't usually see significant cost avoidance in the first year due to the timing and costs involved with selecting and implementing a component solution. Even then, productivity enhancements and the associated cost avoidance begin immediately when an obsolescence solution is put into use. An example of this is when a manufacturer announces the obsolescence of a part or family of parts. The lifecycle management tools are quickly used to identify all affected parts, their associated next higher assembly (usually a circuit card), and their location within the system to determine the total impact. This results in a productivity enhancement that reduces manual labor and errors from missing information.

Although most manufacturers expected lower costs by moving to commercial components, additional costs are now often being applied for data management, obsolescence, qualification, functional and characterization testing, and additional labor due to the lack of documentation. Therefore, the total lifecycle cost of commercial components may approximate the Mil-spec components they replaced. Additional details on these cost areas are included in the following sections.

3.11.2 Increased Testing Costs

Previously, the cost of ensuring that Mil-spec components met their specifications was borne by the manufacturer and included in the cost of the part. Performance and environmental qualification was required for most electronic components used in military systems. Lower failure rates and higher capabilities were identified through screening and testing and helped develop a class of military-grade components that were typically above the norm of what was affordable or viable in the commercial marketplace.

Commercial component manufacturers now produce parts with much higher capabilities and lower failure levels than were available 10 years before. This is due to the increased demand and production lot quantities that results in very dependable components. Capabilities have increased typically in their speed, capacity, and functionality, but not typically in their environment. Consumer electronics' ability to withstand extreme thermal, vibration and shock, and space based application are often unknown. These are not tested, or if tested are not published nor guaranteed by their manufacturers. They also have a reduced need to sell to the military market since the majority of their customers are commercial and now drive their current production and sales. Military system manufacturers must now fund and schedule additional component testing and add that cost to their proposal for each application. This results in costs being multiplied as a single part is used on multiple systems, on multiple programs, by multiple developers, and the customer assumes the final cost.

3.11.3 Reduced Lifecycle Impact on Production Programs

The typical lifecycle for ICs such as microprocessors and Random Access Memory (RAM) has been rapidly decreasing which means that more and more components will become obsolete prior to a program's beginning production. Planned replacements and upgrade paths are potential solutions, but even these (when viable) result in multiple system configurations which increase training and logistics costs.

3.12 Industry Support - Conferences, Initiatives and Working Groups Attended

Over the past 10-15 years, a number of conferences have been developed to provide developers and users the opportunity to review solutions and provide solution developers a forum to market their products. The following sections summarize the most prominent, their functions, and their intended audience.

3.12.1 Conferences

The CMSE National and International Conference, and the annual COTS Conference are two relatively new meetings that have slightly different approaches and audiences, but focus a considerable amount of tracks and presentations on obsolescence. The Commercialization of Military and Space Electronics (CMSE) Conference is targeted toward electronics engineers and applying design approaches and solutions to their typical design problems. Obsolescence is considered an unwanted offshoot of the commercialization trend that should be managed and understood. The COTS Conference, although appearing to focus on COTS as a whole, is more technical and is focused on electrical design using COTS components and off-the shelf equipment.

OEM conferences have also been developed to address obsolescence and provide an internal forum for solution identification and promotion. Lockheed Martin's Mission Critical Enterprise Support (MCES) Conference and Lockheed Martin's Joint Symposium are two vehicles for providing this visibility. These are targeted at identifying internal Lockheed Martin solutions and initiatives from across the corporation. The MCES is more software and Information Technology (IT) oriented since it is sponsored by the Lockheed Martin Enterprise Information Systems (EIS) group. The Joint Symposium is sponsored by Lockheed Martin's Engineering Process Improvement (EPI) group and focuses more on process and initiatives.

In the government arena the NASTC, DMSMS, DMC, and Aging Aircraft Conferences are now being held nationally. Each of these provides a forum for discussing obsolescence, but the Aging Aircraft and the DMSMS Conferences are solely dedicated to solving obsolescence - Aging Aircraft concentrating more on structural, materials, and system life extension issues for military aircraft (Air Force and Navy) and DMSMS concentrating more on the system's components and practices.

There are also European international meetings that address obsolescence, some of them European versions of U.S. conferences and some unique. One specific meeting that was supported as part of this contract was the NATO Maintenance and Supply Agency's (NAMSA) International Conference to educate NATO customers and users on Lockheed Martin's capabilities in the area of obsolescence.

3.12.2 i2 Technologies

As a tool developer, i2 Technologies has two conferences each year, Planet and Directions. Planet focuses more on company decision-makers to introduce new products and provide insight into their wide variety of products and integrated approaches. i2's Directions is more user and system manager oriented, and includes user-group meetings and customer presentations to provide insight on applications, techniques, tips, and solution approaches.

Lockheed Martin participated in several of these conferences during the POMTT project since i2's Supplier Relationship Manager (SRM) tool provides an obsolescence prediction capability and was used in two pilots. Through participation, POMTT provided support and feedback on the POMTT program and also assisted in i2's product development.

3.12.3 Working/Teaming Groups

A number of Working and Teaming groups have now been established in that address obsolescence. Several of these are described in the following sections.

3.12.3.1 LMC's Engineering Process Improvement Center

The purpose of the Engineering Process Improvement's (EPI) Commercial Technology Insertion Process Group (CTI-PG) is to develop methodologies, processes, tools, and roadmaps to aid in inserting commercial electronic technology into LMC products. This includes minimizing obsolescence and maintaining reliability and system effectiveness. The group works to leverage commercial tools and practices as a sub-group of the Electrical Subcouncil.

Some of the activities of the group include:

Components Management Guidelines - This is a single, open, company-accepted plan for the management of components. This document works with standards established and currently in use by international and national standards groups like the IEC and the GEIA. The purpose is to develop a single process within Lockheed Martin that would define a parts management plan in a role as a prime or as an OEM (i.e. Prime would provide ECMP as a template to the OEM for development of a program specific plan. The OEM could either be another Lockheed Martin facility or an external supplier).

Operation of Commercial Electronics in a Military Environment – This is an effort to collect and share recommendations for testing, characterization, and operation of commercial parts in military applications. Methods such as cocooning, assembly heaters, modified operational profiles, advances in ECS technology, etc. will be examined.

Technology Roadmapping - The working group is exploring the effort required to survey industry technologies and develop roadmaps (e.g., SIA roadmap, NEMI roadmap, GEIA roadmap, etc) in an attempt to define likely advances in avionics technology in the future. The group will also attempt to identify technology gaps that are not being fulfilled and coordinate with Lockheed Martin sites for research opportunities by IRAD and CRAD.

Consolidation of Electronic Components Information – This effort is consolidating component DMS information from multiple Lockheed Martin companies and sites by taking obsolescence data, site capabilities, industry associations, and modeling information to better communicate and share information.

Industry Committee Participation – Identification of currently supported industry standards groups has begun to determine the most effective application of personnel and the widest usage of their information.

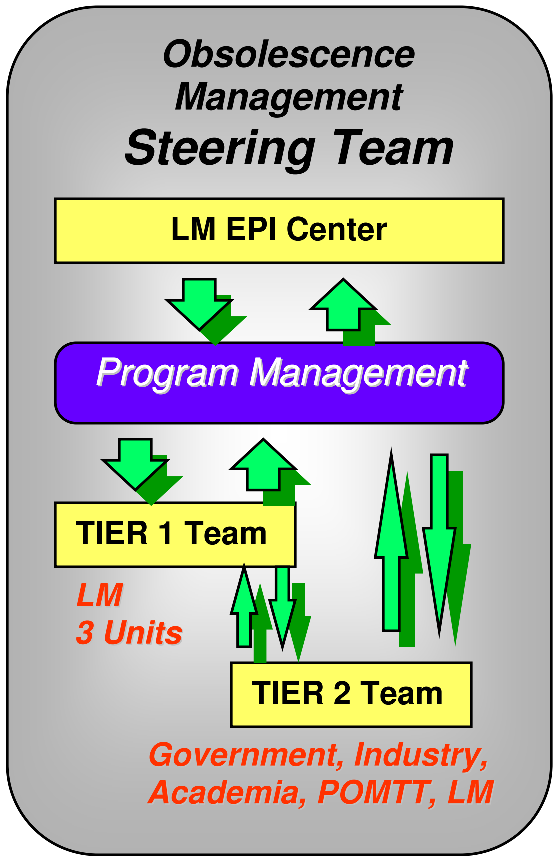
Parts Obsolescence Management Guidelines - This activity used the POMTT tools evaluations and is developing new methods to mitigate the effects of electronic part obsolescence on supporting the producing weapon systems. The results of these evaluations were used to create a guidance document to help users throughout the corporation apply proven tools and techniques in the right instances. Some of these include Electrical and Mechanical Design, Systems Engineering, Components Engineering, Procurement, Quality Assurance, Reliability, and Program Management.

Obsolescence Forecasting – This sub-team is evaluating existing obsolescence algorithms and techniques and is investigating enhancement, investment, or replacement. This will be used to establish more reliable predictions, aid in identifying potential replacement parts, and support the development of more effective tools.

Other Tasks – A Lexicon was created to provide a single dictionary of terms and definitions to provide a basis for commonality throughout the company. A Tools Evaluation Database (TED) was also created as a corporate repository for tool evaluations and has already been populated with tool reviews from a number of company locations.

3.12.3.2 OMST

The Obsolescence Management Steering Committee was originally established as a high-level discussion group that would be involved at multiple companies and government agencies. They would meet periodically to discuss current and emerging trends in obsolescence management and provide direction to other groups and industry activities (See Figure 3.8).



Area 3 -- **Figure 3.8 – Obsolescence Management Steering Team**

The team was started at the beginning of the program and members from many companies and organizations were invited to attend including:

- LM Businesses - Seven Companies (LMEM, LMCS, LMVS, LMTAS, LMFS, LMAS, Sanders)
- LM EPI Center
- ACME/PO Tool Developers
- Government - OUSD-L, GIDEP, DMEA, Logistics Centers
- Industry - PART, AIAA, EIA

- Academia - CALCE University of Maryland, University of Alabama

The purpose of the group was to interface with LM's EPI group, support ACME/PO vendors and design reviews, represent the program within the government and industry, document and release corporate procedures and best practices, and provides training and support to programs. This was all put into place and these tasks are being continued.

However, due to the differences in funding, tool development, and company direction, participation was limited primarily to those ACME/PO tool developers still in operation and the POMTT team. Therefore, the meetings were replaced by open attendance in the POMTT Quarterly Reviews and became more successful towards the end of the project with company and government attendees coming from all over the company and industry including JSF, NASA, C-130J, and F/A-22.

3.12.3.3 DMSMS Working Group

The Diminishing Manufacturing Sources and Material Shortages (DMSMS) Working Group to bring many DoD programs to share information, reduce costs, and measure the effectiveness of the obsolescence program. The group is the DoD focal point for all DMSMS initiatives for the Deputy Under-Secretary of Defense for Logistics & Materiel Readiness.

The Working Group was started in 1994 by and has since been sanctioned by the DoD. Their overall goal is to educate, minimize the cost impacts of obsolescence, and disseminate information through the military services and industry via the Government Industry Data Exchange Program (GIDEP) and other DOD and services agencies. There are two main events at the meetings: an Open Case Review and access to the Teaming Database. Cases are established when programs input their obsolescence data into the Teaming database. Information is limited to actual part number and program usage to protect data confidentiality. A sample of the output for the Open Cases is shown in Table 3.1 below.

Table 3.1 – Example of the DMSMS Teaming Group Open Case Summary

Alert Number	Case Number	Part Number	Mfr Part Number	Generic Part	Program	Alert Description	Case Status	Case Solution
M1A2-4_20_01	3	Part # 1	Vendor Part # 1	508	M1A2	Obsolete	Open	
Aegis 5_01	7	Part # 2	Vendor Part # 2	26LS32	Aegis	Source no longer in production	Open	
GDay7June99	7	Part # 3	Vendor Part # 3	26LS32	AWACS	Open AWACS Case	Open	

All registered database users are allowed to view the cases and provide comments.

There are two subgroups now active in the Working Group. The first is the DoD DMSMS Teaming Group which has three sub-groups:

- ***Active Devices*** – Working microcircuit and semiconductor obsolescence
- ***Chemical*** – Developing a process to help find common solutions for common problems within DoD programs.
- ***Commercial Off-the-Shelf (COTS) Equipment*** – Working with current list of equipment trying to develop a way to work common problems.

The second sub-group of the DoD Working Group is the DoD DMSMS Materiel Sub-Group. This group reviews and coordinates obsolescence issues related to chemicals/materials and has already identified several chemicals/compounds as obsolescence cases. GIDEP maintains the group's database, web page, and information.

3.13 Industry Developed Tools

As recognition of the obsolescence problem increased, OEMs developed their own tools to address their needs. Some of these were spun off to form new companies (i.e., IHS spinning-off from Martin Marietta - Denver) and some were created in response to the recognized need by existing software and tool developers. There were only a couple of existing tools at the beginning of the POMTT program that specifically addressed obsolescence. As a result of EPOI, this number has increased dramatically so that now there are five to ten database tools where only one or two existed previously, two to five decision tools where none existed, and a series of existing design approaches that were proven to address obsolescence through proactive modeling and more efficient reverse engineering. These are summarized in the following paragraphs.

3.13.1 i2/TacTech

i2 Technologies Electronic Database (ED) and TACTRAC lifecycle content were previously two separate entities. The two databases were merged in 2003 and early 2004 and now the TACTRAC database is a subset of the ED database. The TACTRAC tool and database is designed to be a stand-alone resource. The user submits BOMs to the tool and reports on the health of the parts are returned for examination. This requires that some outside source of information for the BOM listing be supplied to the tool. If there have been any configuration changes since the last time the data was imported, the revised BOM must be imported for the assessments to be accurate. i2 Technologies' Supplier Relationship Manager uses the ED in its enterprise solution for the complete management of the components used in company designs. This means that whenever a BOM is matched against the lifecycle content, the most current configuration is automatically input into the LCM tool. The SRM solution supports the ability to create "what if" scenarios with different configurations matched up against the lifecycle content.

Each of the two tools uses different sets of reported data: ED uses Years 'Till End of Life (YTEOL), while TACTRAC uses both Years 'Till Unobtainable (YTU) and Years 'Till

Obsolete (YTO) as measures of the respective data points. LCM determines YTEOL at the technology group level, while TACTRAC supports YTU and YTO at the commodity level. For example, a technology level could be the BiCMOS technology at a certain feature size, while the commodity level could be a 64Kb by one-bit memory device made with a particular technology. LCM predictions are based on factors such as market data, technology, demand, and supply. The ED lifecycle prediction algorithm was re-engineered in the second and third quarters of 2003 and the lifecycle prediction for every component in the database changed. The TACTRAC prediction model is based on statistical component modeling of mortality rates; therefore, when the component is introduced, the end of its life is set to the number of years that items in that commodity generally last. Many parts have been at the end of their life for several years in the database, which implies that the algorithms and models used do not take into account factors that may extend the life of these products.

3.13.2 MTI

Manufacturing Technology, Inc. (MTI) is an aerospace/defense firm that specializes in electronics maintainability issues. MTI partnered with Total Parts Plus which provides component content for MTI's obsolescence management application named AVCOM™. The application is capable of importing and managing multiple platform configurations for multiple indentured BOMs.

3.13.3 IHS

Information Handling Services (IHS) is a worldwide provider of technical content and information solutions for standards, regulations, parts data, design guides, and other technical information. In conjunction with PartMiner®, Inc. they created the CAPS Expert™ tool which is an entirely new search engine for PartMiner®. The database contains information on over 15 million semiconductors, passives, connectors and electromechanical components. Specifically it contains information on over 2.5 million semiconductor devices and on over 3.9 million passive devices.

CAPS Expert®'s capabilities can be extended with CAPS BOM Manager and CAPS Forecast. CAPS BOM Manager is a web based tool that allows the user to upload and cleanse a BOM in a few steps. The uploaded data is augmented with the PartMiner® data to include validated part numbering, standardized descriptions and lifecycle data. The user can subscribe to email notifications that identify parts that have changed status. CAPS Forecast uses the data from the CAPS database, along with sales data and their proprietary interpretation of the Electronic Industry Association's Lifecycle Model. Employing this data they create a risk factor estimate and a lifecycle stage estimate. The risk factor is the numerical interpretation of the EIA-724 Lifecycle Model with the stages (Introduction, Growth, Maturity, Saturation, Decline, and Phase-Out) corresponding to the numbers zero through six, respectively. The lifecycle stage calculation relies on the company's concept of "Zone of Obsolescence" and they report three distinct dates for possible obsolescence dates (Low Date, Average Date, and High Date).

3.13.4 ILS

Since 1979, ILS (Inventory Locator Service) has created and maintained an extremely large virtual marketplace for aviation electronics. They use the Internet to bring buyers and sellers together faster and more efficiently than traditional methods. The company focuses on commercial and general aviation, commercial marine, U.S. Government Department of Defense (DoD), and Industrial Gas Turbine markets. ILS and IHS teamed together to provide the portion of their customer base that they have in common with information on the immediate availability and location of parts linked with technical documentation.

3.13.5 Qstar

In early 2002, the former CEO of TacTech founded Qtec, with its premiere web-based tool, Q-Star. The tool is similar to the old web based TACTRAC tool, with added features to support teaming methods for obsolescence issues. Q-Star currently only handles 900,000 active semiconductors and 1.1 million passive devices; however, the company plans rapid expansion of the types and numbers of parts it covers with the tool. Qtec has established three different methods for using these tools. The first is a subscription to their web-based tool. The second is a private or public system that runs on a dedicated server at the users' facilities. The third option, used by the Department of Defense, is for dual servers with the same reference data on each, with one for private and one for public usage.

3.13.6 Fedlog

The data stored on the FEDLOG compact discs are extracted from the Federal Logistics Information System (FLIS) and are produced by the Defense Logistics Service Center (DLSC). This data contains management and reference data, as well as narrative descriptions, freight, and manufacturer supply data for all National Stock Numbers (NSNs). Searches can be performed using only part characteristics, and wild card searches may be conducted for most items in the system. Distribution of the Fedlog CD's is handled by the Logistics Data Management Center in Huntsville Alabama.

Military units constantly must test themselves to ensure that they can accomplish their intended missions and are ready to meet whatever need arises. The same challenge exists for personnel of the Defense Logistics Agency's (DLA) Defense Logistics Information Service (DLIS), in Battle Creek, Michigan, who use the latest technology to offer logistics information management tools that help keep units well supplied with critical items.

DLIS has adapted the Logistics Information Network (LINK) to increase access and search capabilities as technology changes. LINK uses information from 13 Department of Defense (DOD) and General Services Administration logistics databases to help users locate sources of supply and track the status of their supply requests worldwide.

Several versions of LINK are available to accommodate customers with varying computer capabilities and connectivity. In fact, one of LINK's special characteristics is that it provides logistics information to users in network-poor environments. This makes the system ideal for deployed units and ships. People in these situations normally rely on PC [personal computer] LINK versus the World Wide Web. PC (Personal Computer) LINK uses a "burst" method to send queries and receive responses. Users are connected to the network only during transmissions. Otherwise, all other processing, such as building queries and reading responses, is done locally on their personal computers.

3.13.7 Arrow

Arrow Electronics, Inc. is one of the largest distributors of electronic components in the world. The stated business model is to provide solutions to the technology sector that are directly related to components. They represent over 600 suppliers of components and have greater than 150,000 original equipment manufactures that use their corporate resources. The company provides support for the entire electronic component supply chain. They provide design support, materials planning, inventory management, programming, and assembly services. From a knowledge standpoint, they also provide a "suite" of information services and solutions. The backbone of this suite is Arrow's Ubiquidata™ database (which contains information on over 20 million devices). The emphasis of the database is the combination of the technical data, which includes parameters, data sheets and cross references, and commercial data, which includes industry usage and lifecycle stage. The number of parts with lifecycle data is unknown. Arrow uses the database for their own business applications; they claim that the data is corrected and updated on a consistent basis.

Arrow Electronics' Risk Manager is one of the tools that use the Ubiquidata™ database. The tool is designed to reduce the risk presented by electronic components throughout the product lifecycle. Arrow reports that the tool can identify and help mitigate risk when choosing components by assessing if the part number is valid, and then by assigning a risk factor based on their proprietary data that includes known current production, lifecycle prediction, and known sales. Production status includes the number of manufacturers that are producing the part. The lifecycle prediction is based on a proprietary algorithm. The usage includes both the depth by total sales and breadth by the number and types of manufacturers using the part. Arrow also reports that the tool will provide a relative *procurement risk* score for any combination of selected components. Should a component become unavailable, the tool can help find possible suitable alternatives from available parts.

Arrow Electronics' Global Explorer also uses the Ubiquidata™ database to provide the user with tools and information for using and selecting components. According to Arrow, the Global Explorer has a datasheet on virtually every electronic component available. There are utilities for comparing parameters for multiple components in a side-by-side table. If the user is looking for an item, there are several utilities for searching by parameter, risk attributes, and manufacturer singly or in combination. The user can find alternates through several different means.

A final product, Arrow Electronics' Connectivity Dashboard, is the web portal that acts as the common point to access all of these tools. The Dashboard is designed to allow visibility within an enterprise through the use of "sharing". The tool allows multiple participants with differing functions within an organization access to both the user and the Ubiquidata™ data.

3.13.8 Part Cleansing

Arrow Electronics also has a part cleansing service that uses their own component staff armed with the Ubiquidata™ dataset and their tools to provide part cleansing. Arrow's stated goals with the parts lists are to ensure that the part number is valid for the manufacturer and to alert the user to the status and availability of these parts and part numbers.

3.13.9 PCNalert®

PCNalert® is a web-based tool provided by Supply Edge, Inc. that is intended to be used by Original Equipment Manufacturers (OEMs) for managing the effects of obsolescence by continually monitoring and allowing the user to act upon the changes to their components. The tool provides access to Product Change Notifications (PCNs), End-of-Life notices (EOLs), Alternate Part Numbers, Datasheets, New Product Introductions (NPIs) and other component data. The goal of the system, as envisioned by Supply Edge, Inc., is to provide the necessary visibility to every member in the supply chain, including designers, component engineers, buyers, production teams, project managers and (in limited fashion) suppliers. This would allow every member of the team to be aware of problems as soon as the first warning is issued.

The solution provided through PCNalert® uses the AVLportal as the web-based gateway for accessing their tools. Like most web based portals, it acts as a common interface with an intuitive and consistent look and feel. AVLalert provides a targeted updates of snapshots of components. The snapshots' delivery can be individually directed to several different users based on factors including commodity codes, project, BOM etc. BOMverifier provides real-time PCN and EOL information on-demand. This tool allows a user to securely upload BOMs for immediate details on the status of the components.

3.13.10 SHAI (Stottler, Henke Associates Inc.)

Stottler, Henke Associates, Inc. started work on the Obsolescence Prediction Tool (OPT) for the Navy in 2000. This software-based tool was an attempt to use artificial intelligence algorithms and techniques to predict the lifecycles of parts used in Naval systems. The project was funded over multiple years. However, it was never adopted by the Navy and no additional research for the OPT was funded.

3.13.11 SiliconExpert Technologies

SiliconExpert Technologies is a data management company that focuses on content acquisition, content catalog management, and development of software productivity tools. They perform data validation through data cleansing by analyzing BOM's and component databases for validity, accuracy, duplication, and enrichment of the user's data through second sourcing and continuous review with tools such as ExpertLINK ™.

3.13.12 PartMiner

PartMiner, Inc. is a global supplier of electronic components. It is also an online provider of component information needed by engineers and clients in the electronics industry. In addition, PartMiner provides excess inventory management services and enterprise solutions.

PartMiner Direct is a primary source of electronic components offering competitive pricing on components in stock in its ISO 9002 certified warehouse facility, as well as purchasing services for scheduled (just-in-time) deliveries, vendor consolidation, and bill of materials fulfillment. It also serves as a secondary supplier that can locate hard-to-find, obsolete, and shortage parts for customers using over 6,000 suppliers around the world and an internal inventory database.

The PartMiner Web Site provides online tools and resources such as data sheets and other information on over 18 million electronic components from over 2,000 manufacturers (through collaboration with IHS' CAPS database). Users can search by part number to locate inventory from major component suppliers and compare pricing; they can also make use of an online request-for-quote application.

A relatively unique product, Free Trade Zone allows research in the largest and most comprehensive database of electronic component parts and datasheets in the world, with detailed information on over 15 million parts from over 2,000 manufacturers. Find current price and availability information from the largest virtual inventory on the web. The database allows procurement and design organizations to find alternative sources and manage component obsolescence issues.

3.13.13 Total Parts Plus

Total Parts Plus offers two online obsolescence management tools: Parts Plus and PartsXpert. Parts Plus is the superior tool which offers an abundance of obsolescence management options that meet a variety of needs. PartsXpert provides basic obsolescence management.

Parts Plus and PartsXpert features include (1) a Part Search to search for parts by generic/die or catalog part number, (2) a wildcard feature to expand searches to view part variants, (3) a search for aftermarket sources, and (4) a search for commercial, industrial, and military parts; and to view equivalent parts. A user can review the production status of a part: project its availability in years; obtain an End of Life (EOL) status (if applicable); view form, fit, functionally potential replacement parts; locate aftermarket suppliers and original generic sources; and find hyperlinks to manufacturer web sites.

Parts Plus features include: (1) analytic functions that can be performed on any single Bill-of-Materials (BOM) or across all loaded BOMs; (2) customizable reports, (3) End-of-

Life (EOL) impact analysis on all parts or selected BOMs; (4) powerful query capability to sort by selectable fields such as manufacturers, production status, and part type; and (5) provides part obsolescence predictions on any single BOM or all BOMs-selectable by part type or time frame. It also has an import capability to allow a user to import BOMs with user approved sources in standard MS Excel™ format and assign the parts to boards, boards to boxes, and boxes to systems.

Additional features include an Alert service to provide timely notification of EOL and PCN announcements impacting semiconductors in user BOMs, export structural views, and export special reports and analyses to MS Excel™ to save and use in briefings, reports, and procurement analyses.

3.13.14 Precience

Precience provides component obsolescence lifecycle and supplier management tools and utilities. PartNavigator and Obsolescence Manager are two that are of particular interest to the obsolescence decision maker. They support Bill-Of-Material (BOM) Grading, part investigation, and risk assessment solution. Their application building tools also allow creation of custom workflows to track, manage, and centralize obsolescence management.

3.13.15 PartNavigator

The PartNavigator tool speeds up component selection with parametric search, datasheet, availability and equivalent cross-references and features bi-directional schematic and layout EDA integration. It reads and annotates technical information to all major EDA schematic and layout tools and speeds up component selection with parametric search, current and future availability, EOL, pin, package, exact part number, datasheet, availability and equivalent cross-references. The tool identifies potential alternates across manufacturers and commercial, industrial, or military grades with form-fit-function information. It also automatically generates reports on designs, highlights obsolete parts, sole source situations, short term availability, projected life span, EOL, missing company part numbers, internal MRP/ERP and other data, as well as distributor and contract manufacturer part status. It also integrates decision support data from internal AVL, ERP/MRP and other systems, as well as external supply chain

3.13.16 Prescience's Obsolescence Manager

This tool attempts to mitigate electronic component availability risks throughout a product's lifecycle. It identifies component obsolescence issues with end-of-life (EOL) information and real time notification services. The user can apply cross-referencing to select alternate parts and upload bills of materials (BOMs) to forecast future obsolescence. This is a Web-based application and requires no installation to deploy. Users can also research parts according to form-fit-function, production status, EOL notices, projected availability in years, and perform availability risk assessments. An ability to cross-reference across manufacturers is also included.

Providing a capability to search for parts by generic/die or catalog part number facilitates parts searches and a wildcard feature expands part searches to increase the base of parts queried. They also provide an Alert Service for timely e-mail notification of EOL announcements affecting relevant semiconductors in any BOM and include customizable reports.

3.14 Aftermarket Manufacturers and Suppliers

Another area of obsolescence management that has emerged from the needs of the industry is referred to as the "gray market." This is a group of parts providers that provide finished parts, IC die, IC wafers, production masks, and packaging material purchased from the original manufacturer after they went out of business. These suppliers meet a need in the marketplace by providing another alternative to redesign and are used because their parts are often Form, Fit, and Functionally (F^3I) identical to the original part, but usually at a much higher price. In some cases they can also reverse engineer or manufacture out of production die depending on the complexity and availability of tooling. Included in these obsolete part repositories are Rochester Electronics, Aztec Components Inc., Minco, CPU Technology, Semiconductor Logistics Corp., and Lansdale.

Reverse engineering manufacturers have several different approaches to obsolete parts. Generalized Emulation of Microcircuits (GEM) has an approach that is funded by the Defense Logistics Agency (DLA) to reverse engineer the design of basic logic devices and simpler IC functions and produce functionally (and sometimes form and fit) equivalent parts. They use Field Programmable Gate Arrays (FPGA) that now contain up to 20,000 gates. Costs can be very reasonable since they maintain a library of previously engineered designs. However, new design projects can be expensive, especially more complex devices, since it is essentially a redesign of the original part.

VP Technologies, on the other hand, uses customized software programs and any available component data (from data book schematics to NetLists) to produce functionally equivalent, tailorable, user-owned Intellectual Property (IP) devices that can replace the original.

Several other companies also reverse-engineer designs, but the user is normally delivered a replacement part using a compatible technology that may or may not exist the next time a part is needed. Also, the manufacturer retains the IP unless the customer pays a higher cost.

3.15 Resource Organizations

A number of resources exist in the way of industrial associations and government agencies. These include the Government Industry Data Exchange Program (GIDEP), the Defense MicroElectronics Agency (DMEA), the Defense Semiconductor Association, the Defense Supply Centers in Columbus, OH and Philadelphia, PA, and others.

3.15.1 GIDEP

GIDEP's Diminishing Manufacturing Sources and Material Shortages (DMSMS) notices originate when a part manufacturer announces that a part or a production line will be discontinued. The majority of the DMSMS notices are issued on piece parts, especially in the electronics area (primarily microcircuits); however, DMSMS also occurs at the module, component, equipment, or other system indenture level. GIDEP is designated as the Department of Defense centralized database for managing and disseminating DMSMS information. The database contains data for parts manufactured in accordance with military or government specification and commercial parts.

GIDEP works closely with different government activities on several DMSMS projects that will eventually be migrated to GIDEP system. These projects include the DMS Shared Data Warehouse, DMSMS Prediction Tool, and Army DMS Info System. Future migration of these systems in GIDEP would facilitate GIDEP's role as the central repository of data for DMS management.

3.15.2 DMEA

The Defense MicroElectronics Agency (DMEA) was created to provide more consistent and longer-term support for defense systems across all military services. DMEA was formed under the Office of the Secretary of Defense (OSD) as a center for microelectronics acquisition support, with engineering facilities and personnel who work with the major defense contractors and the semiconductor industry. DMEA currently supports the Army, Navy, Air Force, Marines, Department of Homeland Security, Department of Energy, Department of Transportation, and Department of Justice, as well as defense contractors and international programs in allied nations.

DMEA provides the Flexible Foundry approach that is a series of intellectual property agreements with original technology providers to allow obsolete processes to be reproduced at DMEA's and key industry partner's facilities. These agreements enable DMEA to support obsolete processes and facilitate their production as needed for fielded systems.

3.15.3 Defense Semiconductor Association (DSA)

The Defense Semiconductor Association, located in Columbus Ohio, is part of the Defense Supply Center Columbus (DSCC). Its principal members include Thomas Chakupurakal, PhD, David Robinson (DMSMS), and GEM Program Manager at DSCC. DSA provides a vehicle for DoD agencies and industry representatives to work together and has two main objectives: (1) ensure the availability of radiation tolerant devices and (2) provide affordable solutions to DMS issues.

3.15.4 DLIS

The Defense Logistics Information Service is tasked with creating, obtaining, managing, and integrating logistics data for DoD, federal, and other users. They are the DoD's primary logistics information broker for all military services. They are tasked with helping reduce costs, improve efficiency, and increase effectiveness by acting as a central repository for data and information. They provide access to Defense Logistics Agency (DLA) data, service and program data, government business data, program documents and bills-of-materials, environmental management data, Federal Supply Classes (FSC), and Commercial and Government Agency (CAGE) codes.

3.15.5 DSCC and DSCP

The Defense Supply Center Columbus (DSCC) and Defense Supply Center Philadelphia (DSCP) are the DLA's centers for DoD supply and inventorying. The Philadelphia center provides clothing and textiles, general and industrial needs, medical supplies, and subsistence items (food and rations). The Columbus center focuses on supplying the needs of the fielded weapons systems including components, materials, military specifications and documents, and part and manufacturer qualifications.

3.16 OEM-Developed Tools

There are a number of homegrown tools developed throughout Lockheed Martin and BAE; however, very few directly address obsolescence. The majority of these consist of databases to capture obsolescence case history data. Additional work continues to be performed to develop additional tools that can address other need areas. Decision support and obsolescence prediction are two functions that are being addressed.

3.16.1 Lockheed Martin Developed Tools

Lockheed Martin has developed a tool for obsolescence decision support which resulted from their experiences in the NGIT RADSS 2000 Pilot evaluation. The Obsolescence Decision Tool (ODT) helps users reach obsolescence decisions more quickly. Also, new development has begun on exploring new algorithms for more precise obsolescence predictions. This tool is discussed in more detail in the Northrop Grumman Information Technology RADSS 2000 production pilot in Section 8.

3.16.2 BAE (HDA)

BAE Systems Controls (BAE) has an in-house component data management system that addresses obsolescence. The Obsolescence Management System is comprised of three major areas: Part Selection, Part Monitoring, and Configuration Analysis. The Hardware Design Automation (HDA) system is the focal point for each area. HAD is the collection of preferred components for part selection, component data for part monitoring, and confighuration analysis to allow the lowest cost management of designs. Obsolescence data, such as End-Of-Life Date, is included as part of the HAD system and is similar to the commercially available i2 Lifecycle Management (LCM) tool.

Prior to acquisition of Lockheed Martin's Control Systems Division, BAE had begun internal development of a part selection and support tool. Prior to its release, LCM was reviewed as possible complimentary tools to HAD; however, delays in the release of LCM along with its recurring licensing costs were the primary reasons for declining further review.

Section 4

POMTT Contract Requirements

This section defines the contractual requirements and schedule, summarizes the major accomplishments for each year, provides general details about the tools and technologies to be evaluated, describes the conferences, workshops, and symposiums attended and supported, and explains the subcontracts associated with the program.

4.1 Program Requirements

The primary task of the POMTT program was to evaluate newly emerging obsolescence management tools and technologies, and develop processes and procedures related to their application. The program would also recommend the best value solutions and support insertion, upgrade, and integration of these commercial tools/technologies throughout Lockheed Martin. This was to be performed through the following high level tasks:

1. Establish a comprehensive program
2. Form and initiate an Obsolescence Management Steering Team (OMST)
3. Benchmark existing obsolescence management procedures
4. Develop a standardized set of metrics to measure the effectiveness of current and future obsolescence management tools and procedures.
5. Establish technical liaisons with software vendors and participate in preliminary design reviews.
6. Develop new and/or revise processes for obsolescence management.
7. Promote sharing of data, feedback and recommendations, and maintain an active industry presence.

Each of these was further defined to provide a framework for the performance of the contract. A series of yearly program plans, schedules, and tasks were established.

TASK 1 – Establish a Comprehensive Program

This task was to create a team approach by subcontracting other Lockheed Martin sites to bring their expertise and potential participating programs into the project. This would help achieve the widest diversity of requirements and needs. A schedule was established, key Points-Of-Contacts (POCs) were defined for each set of tools/ technologies, and roles were defined to help accelerate the development, installation, and evaluation of the tools for the pilot demonstrations.

TASK 2 – Form an Obsolescence Management Steering Team (OMST)

The OMST was established early on to support technical interchange meetings with tool vendors. This would allow greater involvement in the tool development and solicitation of their input for development of the evaluation criteria and metrics.

TASK 3 – Benchmark Existing Obsolescence Management Procedures

In order to measure the effectiveness of the tools, tasks were established to evaluate the current tools and business practices involved in obsolescence management. This was performed at each of the participating sites in a variety of ways. Processes, procedures, tools, metrics, and manpower levels of effort were investigated to identify any internal or commercial solutions already being applied.

TASK 4 – Develop a Standardized Set of Metrics to Measure the Effectiveness of Current and Future Obsolescence Management Tools and Procedures

Work was begun to measure these existing obsolescence mitigation approaches, particularly focusing on existing design tools and solutions (life-of-type buys, emulation, redesign, alternate source development, etc.). Measurement was performed of the effective cycle times for these solutions and commercial technology trends were researched via vendor surveys and on-site visits. Searches were also made of existing lessons-learned datasets to assist in the creation of metrics.

TASK 5 – Establish Technical Liaisons with Software Vendors and Participate in Preliminary Design Reviews

Proprietary Information Agreements were established with each of the POMT vendors to allow data communication early on and beta testing of the software tools later in the program. These liaisons would provide as-required technical support. They would allow participation in design reviews for each of the software vendors, and would help POMTT monitor the progress of each tool's development to ensure that the release schedule would be consistent with the overall program plan.

TASK 6 – Develop New and/or Revise Processes for Obsolescence Management

This established relationships with the pilot program candidates to facilitate the development, documentation, and revision of processes for obsolescence management at the program, site, division, and corporate level.

TASK 7 – Promote Sharing of Data, Feedback and Recommendations, and Maintain an Active Industry Presence

POMTT prepared and presented numerous abstracts and papers on the EPO program at obsolescence management forums to solicit feedback and recommendations from government and industry participants. This included industry, national, and international conferences, symposiums, working groups, and technical seminars.

4.2 OMST

The first Obsolescence Management Steering Team Meeting was held in December 1999, at LMM&FC-Dallas and brought together representatives from all of the POMTT participants. It served as an open forum for discussion and communication. The meeting had presentations from each of the Lockheed Martin Pilot Programs (Dallas, Control Systems, and Orlando) and included plans, schedules, and potential pilot programs for year 2000 and beyond. Following the presentations, the meeting was started with a general discussion to gather feedback from the POMTT tool developers. Potential solutions for many of these issues were proposed at the meeting and were reviewed with AFRL at the February Year 2000 Program Plan Review meeting. Some of these issues required additional negotiation before they were solved. Some of the key issues are summarized as follows:

1) Schedule coordination is critical due to the large number of participants.
2) Tool support requirements (hardware, services, and training) must be identified.
3) The program 4-year time span for the program is too long and several contracts are scheduled to end before the evaluation begins. Additionally, there are costs associated with agreements, licenses, custom user interfaces, and data gathering that need to be funded.
4) Some tools may not fit the application's environment.
5) Coordination is needed between pilots and tool developers, between tool developers, and for meetings to reduce travel and duplication of efforts.
6) Software licenses may be needed for evaluations and may require funding and flow-down for additional users.
7) A common Non-Disclosure Agreement (NDA) and Statement Of Work (SOW) would simplify the POMTT effort.
8) Intellectual properties (patents and inventions), software security, data confidentiality, and coverage by NDAs need to be addressed.

As the program progressed additional OMST meetings were held. The second meeting at Northrop Grumman continued to work towards defining the tool applications and the pilots. Some additional, more specifically focused, key issues were discussed:

1) The tools will be selected as to their relevance to the evaluating companies and their pilot programs.
2) Existing ACME/PO contract extensions and funding for tools will continue to be handled on a case-by-case basis.
3) There is no requirement for AFRL funding for tool installation.
4) The tool developers are expected to support installation and training as they would in their marketing of any other commercial product.

These issues were addressed and work begun on establishing contacts with each of the tool developers. One topic that was critical to the progress of the pilots and application of the tools was the tool delivery status. Overall, the OMST members seemed satisfied with the progress to date and the LMC-developed backup approach to address tools that were being delayed.

An OMST meeting was held following the POMTT Customer Review on January 10, 2001. POMTT presented a summary of initial tool selections to the tool developers and a detailed explanation of our metrics development and plan. However, discussions with

Northrop Grumman revealed a difference with their metrics approach, and follow-up discussions were scheduled to see if the two could be consolidated.

At the Electronic Parts Obsolescence Initiative (EPOI) Workshop in Atlanta, GA (3rd Quarter 2001), another meeting of the Obsolescence Management Steering Committee was held. This meeting's purpose was to discuss the need for further scheduled OMST meetings due to the fact that the tool evaluations were underway and that internal and external meeting, technical interchanges, EPOI Workshops, and conferences were now providing the direction once led by the OMST. It was agreed that the meetings could be held on an as-needed basis, such as in conjunction with an EPOI Program Manager's meeting, or as part of the LMC-internal Engineering Process Improvement (EPI) Electrical Subcouncil meeting process. The date and location of the subsequent meetings would be announced as needed. Therefore, by mid-2002, the majority of the internal tasks relating to the OMST were being coordinated through Lockheed Martin's Commercial Technology Insertion Process Group (CTI-PG). External tasks continued to be met through attendance and presentations at meetings, industry conferences, and symposiums.

4.3 Schedule

The entire POMTT Program Plan includes the tasks associated with completion of the pilot programs and other activities. The chart below (Figure 4.1) is the initial program schedule established for the program. Although the overall structure is defined, it should be noted that some tasks had not yet been defined and would be added later.

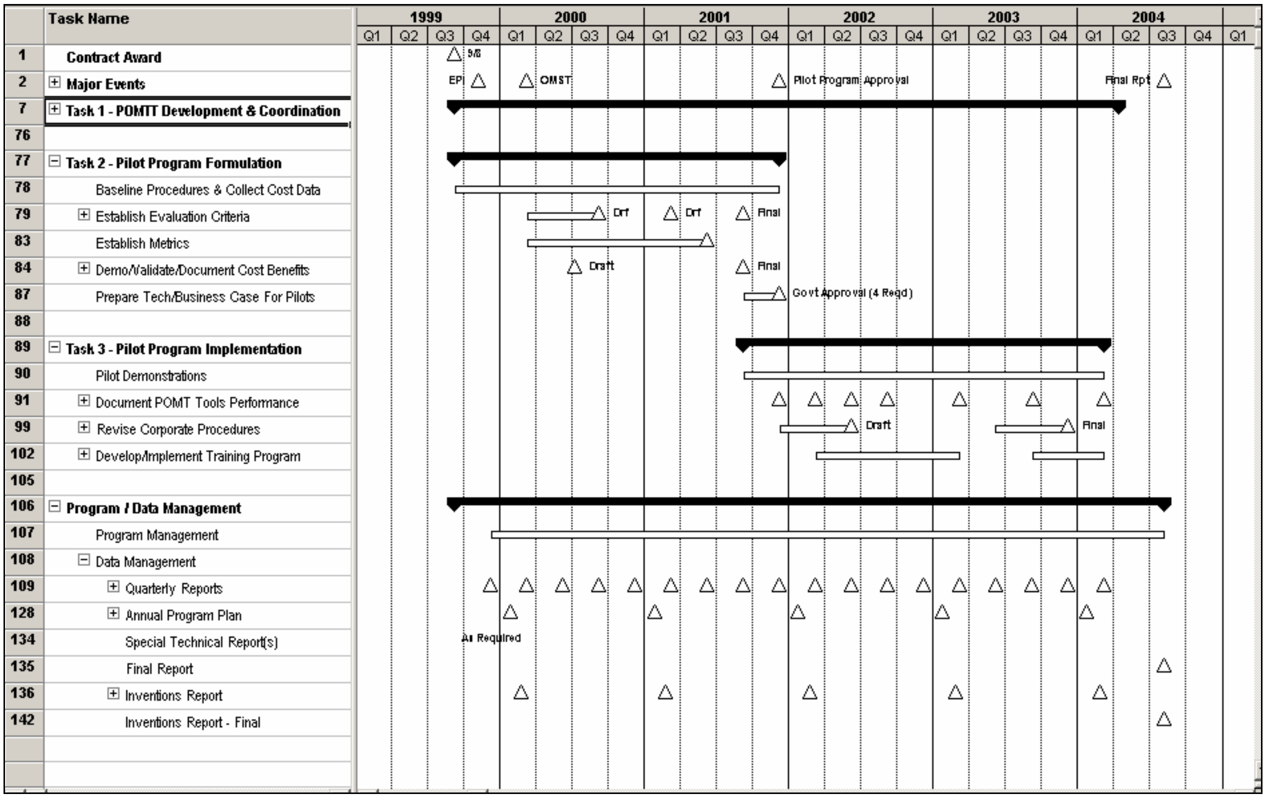


Figure 4.1 – Initial POMTT Program Schedule

4.3.1 1999 Summary

As the contract progressed, continuous reviews of the POMTT pilot partners, Lockheed Martin Control Systems (LMCS) (now BAE Systems Controls) and Missiles & Fire Control – Dallas (M&FC-D), were held to identify schedules, manpower estimates, upcoming activities, potential software tool usage, and possible pilot programs. The initial goals for the project participants were the review and selection of the tool vendors for the potential pilots. This requires that:

1) a review of each tool and technology be completed
2) draft business cases be developed to help identify and narrow the field of likely pilot programs
3) a draft analysis tool and metrics recommendations be established.

Program reviews provided the best approach to ensure a common effort was being applied towards these goals. Unfortunately, the unavailability of several tools limited their complete. Early in the program, several tools were used only in the early concept phase, and gathering program support was difficult since the potential pilot programs were primarily interested in proven practices that limited their risk. However, as the program matured, each of the tools was published and most were made available for use.

4.3.2 2000 Summary

Year 2000's primary goal was the review and selection of the most viable tools for potential pilots. The follow-on goal for 2001 was the establishment of pilot programs for each of the selected tools. Although development of some tools was still continuing, pilots were structured and performed as the tools, time, location, and manpower became available. For example; POMTT supported and attended meetings and training on the RADSS 2000 tool and continued the process through its development. The program also participated in the final TRW Final Program Review in Dayton while holding a number of technical interchanges and meetings with i2 in preparation for a future LCM demo.

At each site, multiple program internal IRAD reviews were supported at various times throughout the program. It often became clear that, because of the "845" cost-share status, funding and participation would have been reduced multiple times over, but was not. One of the factors of success was due to the effect cost-sharing had on the schedule and length of the program.

4.3.3 2001 Summary

The goal for 2001 was the establishment of pilot programs for each of the selected tools and considerable progress had been made. By the end of the year, each of the planned pilots had their draft business cases prepared; however, not all of the tools or programs were ready to be implemented in a pilot. The terrorist attacks of September 11th delayed some work and forced the cancellation of a scheduled demo and the product rollout of i2's LCM (which was subsequently pushed out to late 2002). Additionally, company issues at i2 (support, expertise, and manpower) and changes in the stock market due to the technology boom bust made it very difficult to obtain coordinated information or even get responses to requests for information.

At a POMTT Quarterly Review held at the LMC Dayton Field office on August 14, 2001, discussions were held with AFRL MANTECH management (Bill Russell and Brandon Lovett) to discuss approval for Orlando's VP Technologies/Longbow Technology Pilot. However, because of outstanding unresolved issues, it was not formally presented for pilot approval. Additional discussions established the approval requirements for the Production Pilots and the Cost Methodology plus-up contract. Also, preliminary metrics had been established and were being reviewed for their input into the PATA tool.

Reluctance by programs at each of the sites to undertake a hard pilot using the new tools required POMTT to take a multi-step approach to a hard pilot. To build some trust and interest with these programs, Orlando used an FPGA to ASIC conversion technology pilot to demonstrate the type of conversion and show the potential of follow-on projects. At BAE, interest in VP was tempered by the fact that VP had never taken a model through complete synthesis to silicon. Therefore, they decided to reduce risk by discussing a potential teaming agreement between VP and another company that has a foundry or experience in taking a design through the production process.

By this time, a number of potential projects had been proposed and work was ongoing to establish turn-on and completion dates. They are summarized as follows:

Orlando

VP Technologies / Longbow Missile FPGA Soft Pilot (complete 1/2002)
VP Technologies / JASSM FPGA Hard Pilot (2nd Qtr 2002)
RADSS Complex Part Model / LANTIRN Soft Pilot (1st Qtr 2002)
RADSS Complex Part Model / SNIPER XR Hard Pilot (3rd Qtr 2002)
i2 / JASSM Hard Pilot (3rd Qtr 2002)
i2 / LANTIRN Soft Pilot (3rd Qtr 2002)

BAE

i2 / HDA Soft Pilot (1st Qtr 2002)
VP Technologies Mil-STD-1750 / C-17 Hard Pilot (1st Qtr 2002)
Georgia Tech & Motorola PoF / Universal CPU Soft Pilot (1st Qtr 2002)

Dallas

VP Technologies Z8002 / MLRS & F-16 Hard Pilot (2nd Qtr 2002)
TRW EDAptive / PAC 3 & LOCAAS SLTA Hard Pilot (2nd Qtr 2002)
TRW Synopsis / PAC 3 & LOCAAS Synthesis Hard Pilot (2nd Qtr 2002)

It was agreed at the 2001 POMTT Year End Review (held December 4-5, 2001 in Dayton, OH) that soft pilots did not require AFRL written contractual approval and could proceed after being presented to AFRL. However, all hard pilots required AFRL presentation and written contractual approval before official acceptance as a hard pilot.

4.3.4 2002 Summary

The primary goal for 2002 was the establishment of pilot programs for each of the selected tools, their approval, and turn-on. At the 2001 Year-End Review, several soft pilots were presented that were progressing to approval for both production and technology pilot status. One soft pilot, the application of VP Technologies RASSP VHDL design methodology as applied to the Longbow program's FPGA to ASIC redesign, was completed. A new potential pilot was also established in January for a detailed analysis of the potential integration of the Mitigation Obsolescence Cost Analysis (MOCA), RADSS-2000, and Integrated Cost Estimation (ICE) tools by the former Lockheed Martin Naval Electronics and Sensor Systems (NE&SS) facility for a contract plus-up. The remaining major pilot business cases were presented and approved for Orlando's LANTIRN/IRST/RADSS 2000 and JASSM/i2 SRM pilots, and Dallas' TRW SLTA/TACMS and i2 VIP Content Data/F/A-22 pilot.

4.3.5 2003 Summary

The primary goal for 2003 was the start-up, application, and completion of the majority of the pilot programs. POMTT took the appropriate steps towards the installation of the tools, development, and completion of the pilot. Around this time, internal production programs began to recognize their need for obsolescence solutions and actively pursued tools for release and application to their personnel. Additionally, the pilots are being widely promoted through internal Lockheed Martin meetings and teams, as well as industry conferences, working groups, and exhibitions. The Orlando LANTIRN/IRST/RADSS 2000 and JASSM/i2 SRM pilots were completed at the end of the year and one additional technology pilot using MOCA on the TADS Modernization (MTADS) program was started and completed.

4.3.6 <u>2004 Summary</u>

In 2004, two additional pilots were identified: Orlando's Boeing/Hellfire ASIC, and Dallas' Production Resource Allocation Automation (PRADA)/PCB Manufacturing Technology pilot. Figure 4.2 shows the final POMTT program plan with the current status of the program.

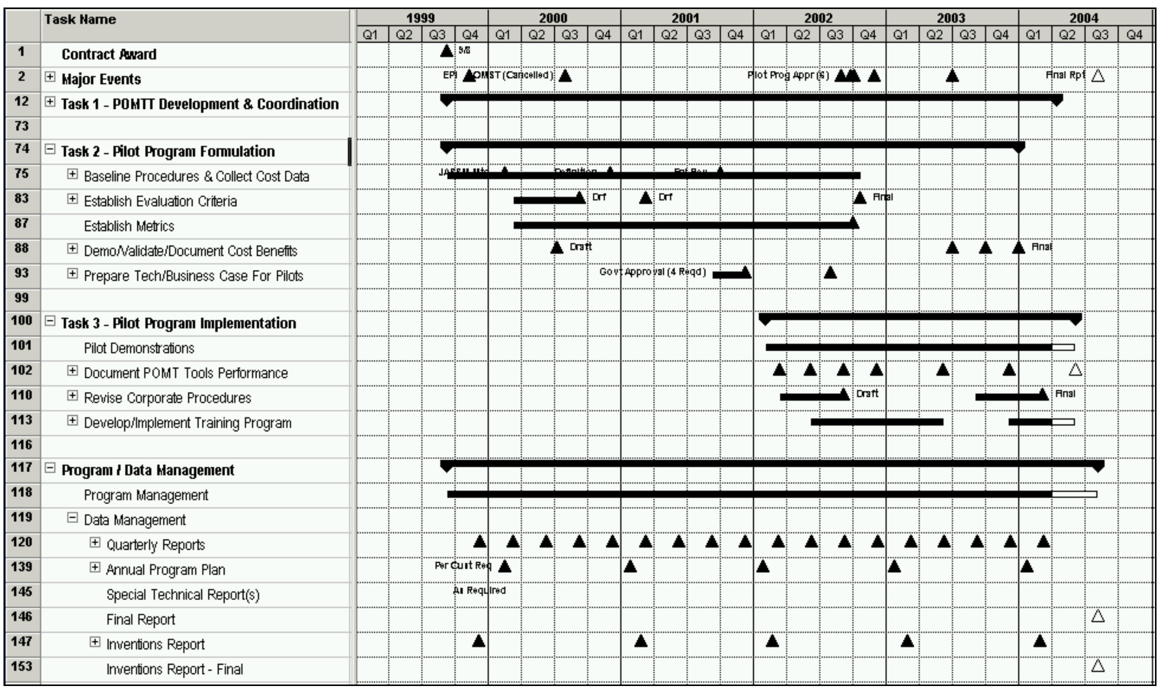


Figure 4.2 – Final POMTT Program Schedule

As can be seen from the schedule, most of the pilots were completed on schedule. Training, education, and development on procedures and new tools continued throughout the entire period at the sites across LMC and BAE.

Only one major change was made to the program schedule which was to add a ninety-day no-cost extension to the end to allow completion of two pilots at LMM&FC-Dallas. This was made necessary after additional difficulties were encountered with the software from EDAptive, and after Trey Fixico was reassigned to another project.

4.4 Pilots

The POMTT contract required a total of six pilots to be performed. Four of these would be "Production" Pilots and two would be "Technology" Pilots. The Production Pilots would actually be used by the participating program(s) to make a change to the system based on the tool's result. The Technology Pilots would also be affiliated with programs but would only use program participation or data. They would not be required to affect the production of the system.

The POMTT program completed the contract with five production pilot evaluations and five technology pilots completed. Summarized, these are:

Production Pilots

- RADSS 2000 & Obsolescence Decision Tool (ODT) / LANTIRN IRST
- i2 LifeCycle Manager (LCM) / JASSM
- Georgia Tech-Northrop Grumman PoF / FADEC, C-17, F-35, F-18, A-10
- Automated Obsolescence Assessment (AOA) / F/A-22
- System Level Test Automation (SLTA) / TACMS

Technology Pilots

- MOCA Obsolescence Cost Analysis / MTADS
- Boeing Rapid Retargeting / Hellfire Missile
- RADSS 2000 / Production Resource Allocation Automation (PRADA) PCB Manufacturing Technology
- VP Technologies / Longbow Missile
- RADSS 2000 / Dallas PCB Mfg. Product Resource Allocation Automation (PRADA)

One additional pilot at BAE with VP Technologies for the C-17's flight controls is still being pursued but has not yet begun. BAE has stated that they plan to continue pursuit of this project even after their participation in the program officially ends. This pilot is the evaluation of the VP Technologies, the Cypress CY7C960 VME Slave processor, which was delayed primarily due to problems negotiating Intellectual Property (IP) rights.

4.5 Deliverables

There were three deliverables required as part of the POMTT contract: Quarterly Reports, Yearly Invention Reports, and a Final Report. All of the Quarterly and Yearly Invention Reports have been delivered and this document will fulfill the Final report requirement.

4.6 Tools and Methodologies Overviews

This section provides overviews concerning each of the tool and technologies provided by EPOI. These were reviewed by the participating sites/companies to determine their applicability to their needs.

4.6.1 ACME

The Application of Commercially Manufactured Electronics (ACME) program focused more on the military application and use of commercial components. It provided tools and technologies from four participants: Georgia Tech and Northrop Grumman, Boeing, Motorola, and Titan Systems (formerly Averstar) and Northrop Grumman. These are described further in the following sections.

4.6.1.1 Georgia Tech / Northrop

Georgia Tech, through funding from Northrop Grumman, developed a finite element based reliability model for Ball Grid Arrays. This work integrates electrical, mechanical, and environmental factors into models that address problems such as die cracking, solder joint failure, fatigue life, and die related failures such as interfacial fracture and interfacial adhesion. These physics-of-failure based representations are correlated with real world data and, once validated, can be extrapolated to new materials, processes, and designs.

The primary purpose of these models is to quickly assess IC-level, package-level, and system-level performance and reliability and to reduce costs from additional testing, qualification, and characterization. The results can also help develop guidelines to improve future designs with respect to environmental performance and reliability.

4.6.1.2 Boeing COTS Reliability Validation

Boeing's intent to use commercially produced parts for military applications required that they be able to enhance and validate the selected part's reliability based on their manufacturing technology and processes. These must also be correlated to the reliability data obtained from the part's actual operational environment. This would be done by selecting representative military electronics application components, identifying the parameters that impact their reliability, and using both factory and field return data to provide the distribution values of critical parameters.

It was well known that there was insufficient correlation for field returns and failure analysis, and little to no validation for high-density packaging (such as BGAs) for military/avionics applications. Also, little work is performed for newer technologies such as CSP, Micro-BGAs and Flip Chips.

Boeing wanted to establish a suite of integrated mechanical, thermal, and acoustic analysis tools that were compatible with industry practices and standards that were faster and validated. They also wanted to develop an environmental test capability that included thermal shock, cycling, and aging in various humidity and altitude environments.

They did this through a survey in which they selected potential component candidates, gathered field return data, identified failure modes, and performed sensitivity analyses. They would use this data to create Physics-of-Failure (PoF) based models and would correlate them with field return data.

4.6.1.3 Motorola Reliability

Motorola's project was to use their cell phone field return data to aid them in developing reliability models for commercial components. They wanted to create a comprehensive approach to system reliability prediction for electronic components and board level systems by creating an integrated toolset to model the interplay between multiple failure mechanisms.

They examined existing failure prediction methods, analyzed and upgraded existing software tools, and developed methodologies to compare reliability prediction with field return data collected on similar components in commercial products. This effort was built using existing single-mechanism and physics-of-failure reliability models.

Motorola next developed a software package implementing a trained neural network to integrate several of these diverse reliability models to predict total system reliability of both component and board level products in a variety of operating conditions. The software also included a material database including field-return data and a graphical user interface. Motorola correlated these predicted methods with a commercial field return database for future selection and qualification of parts for obsolescence management.

4.6.1.4 Boeing Mixed Signal ASICs

Boeing expanded their existing digital design capabilities to encompass mixed signal design and enable the production of small quantity ICs and specialized ASICs through licensing agreements with commercial foundries. They did this by analyzing the use of commercially produced parts in military applications by enhancing and validating software tools to predict and assess the reliability of parts. They established a mixed signal cell library that included standard cell, macrocell, custom cell, and synthesis libraries, and explored the use of tools for automatic layout. This allowed rapid conversion from one foundry to another and reduced procurement costs through more simplified development of alternate sources. It also helped assure more consistent sources of supply for critical parts by providing the ability to more easily retarget them to a new process.

4.6.1.5 Northrop/Titan POET

Northrop evaluated external obsolescence management tools and their own internally developed tools and integrated them through a web-based front end called the Parts Obsolescence Engineering Toolkit (POET). POET uses the Rosetta System Level Description Language (SLDL) to integrate physics of failure, design for the environment, reliability prediction, verification of embedded intellectual property, and life cycle management tools. The purpose was to more efficiently capture, define, and maintain the data associated with COTS devices/processes. This data can then be used to evaluate the technology trends and emerging system obsolescence and upgrade assessment needs, which are then employed to accurately evaluate and capture environmental, assembly, and obsolescence potential of components.

The benefits of this integrated design simulation approach are a more defined process, a reduction in manufacturing issues, standardized design guidelines and models, and an integrated obsolescence management approach through early involvement in the design process.

Titan Systems performed most of the actual work for Northrop and purchased Averstar in early 2000. They subsequently named it Titan Systems' Averstar Group. Later it was renamed Titan Systems.

4.6.2 PO Tools/Methodologies

The Parts Obsolescence (PO) contract approached the obsolescence problem from a different perspective. These tools and technologies were focused more on the military service's needs, such as existing parts going out of stock and the rapid identification of replacements.

4.6.2.1 TRW SLDL

TRW fostered development of two software programs: one to simulate a system at a behavioral level, and the other to automate the test vector generation process. These would then be used to create a top-down system level design modeling approach to support virtual system behavioral synthesis and electronics test vector generation.

The first tool selected was Synopsys' Behavioral Product Re-engineering (BPR) tool that is based upon their VHDL behavioral synthesis CAD environment (Behavioral Compiler) and integrated with Synopsys' Design Environment (SDE). The BPR tool will synthesize RTL and VITAL level simulation models directly from the System Level Description Language (SLDL).

The second tool consists of a Design Verification Test Generation Tool (DVTG) that was developed by Dr. Perry Alexander (previously from the University of Illinois, and currently with the University of Kansas). The tool has been commercialized by EDAptive Computing, Inc. and partially automates the test development process by generating test vectors for WAVES VHDL Test Benches using the requirement specifications created in SLDL.

Using these two system level design software tools, engineers can plan for and facilitate re-engineering over a system's entire lifecycle. Advantages include the ability to more efficiently re-engineer an existing design, and to design products that minimize the impacts of obsolescence.

4.6.2.2 VP Technologies

VP Technologies applied concepts developed by Dr. Vijay Madisetti (at the Georgia Institute of Technology) to more efficiently convert legacy designs to newer technologies. The approach is called Parametric Hardware Modeling (PHM) and helps automate the legacy design conversion process that is currently done manually by most Original Equipment Manufacturers (OEMs).

VP Technologies used their experience in creating simulatable and synthesizable models for board assemblies and individual chips, and microprocessors to develop software utilities and programs that can be used to redesign or create new designs using the VHSIC (Very High Speed Integrated Circuit) Hardware Description Language (VHDL). VP has continued development of their existing toolsets, component model libraries, virtual prototyping services, and virtual libraries and uses these in the service they provide. This approach to design capture promotes enhancements to form, fit, and functional characteristics and modifications to existing systems. The use of executable requirements, specifications, and virtual prototypes also reduce the time required to design and field electronic systems.

4.6.2.3 Northrop Grumman Information Technologies (NGIT) RADSS 2000

Litton expanded the application of their existing decision support tool (Resource Allocation Decision Support System - RADSS) to parts obsolescence decision criteria by adding cost factors data. Their intent was to provide a decision support tool and an integrated business process to make cost-effective parts obsolescence decisions by taking all relevant variables into consideration. RADSS 2000 is a stand-alone, PC-based software program that provides upper level managers with a dynamic decision support system for complex decision models. They also developed a Parts Obsolescence Management Roadmap (a business process model) to aid system managers in determining the most cost-effective parts obsolescence solution with consideration of the many variables. They reviewed and assessed current Air Force Air Logistics Center's parts obsolescence analysis, assessment, decision processes, policies and practices to identify the types of decisions, decision makers, the decision criteria used, and how they all fit together in the overall process.

Northrop Grumman purchased Litton TASC early in 2001 and acquired the RADSS 2000 tool as a part of its assets. It continued to sell its products as Northrop Grumman Information Technologies (NGIT).

4.6.2.4 i2 Technologies

Aspect, and later i2 Technologies, created a large data management system that provides component-supplier management and engineering design data to support product data management. They also developed the Life Cycle Manager (LCM) to more accurately predict future obsolescence and integrated it with their existing system capabilities.

Their initial purpose was to develop an add-on module to their existing commercial product, adapt it for use in military and commercial applications, and provide graphical analysis and obsolescence reporting for more informed decision-making. They teamed with Raytheon Systems Company to develop a user-needs (or "Use-Case") oriented approach.

The approach included collecting all relevant obsolescence data and associated information (market trend information, component information, etc.) and making it searchable and accessible. Next they obtained the expertise and tools of the TacTech Corporation to analyze the data and develop plans based on the results of the analysis. The program was to provide a lower-risk approach to cost-effective analysis and management of electronic parts obsolescence for both new and existing systems. It also planned to leverage commercially available tools and data content and promote integration with third party software and legacy systems.

The Aspect Development Corporation was purchased by i2 Technologies in 2000 and the Life Cycle Manager functionality was subsequently rolled into their Supplier Relationship Manager (SRM) tool.

4.6.3 Cost Methodology (Plus-Up)

LM also received and evaluated a proposal from Lockheed Martin Naval Electronics and Surveillance Systems (NE&SS) in Manassas, VA, for a 65% cost share effort for 2000 as a pilot partner. This proposal was the genesis for an add-on contract to evaluate three EPOI-related tools and one LMC-developed tool.

4.6.3.1 Frontier ICE

The Integrated Cost Estimation Tool (ICE) had an original goal to automate the manual processes of the Air Force cost estimating departments. This manual process involved retrieving data (typically from the Air Force Total Ownership Cost, AFTOC Database, or other sources), preparing costing spreadsheets, and printing summary/detailed information. ICE now does this in a semi-automated way via a TurboTax-type Graphical User Interface. Thus, ICE represents a pleasant, intuitive and functional user interface shell that links the Air Force AFTOC historical database to common commercial and government costing tools such as Price Systems Suite (from Price Systems), SEER-SEM (and SEER-H from Galorath, Inc.), and the government CORE analysis model.

ICE streamlines the “necessary user data inputs” as opposed to a detailed listing of inputs that Price and SEER normally require of the user. It leverages slider bars, scales, numeric inputs, and other simple input mechanisms for fast mouse-controlled inputs. Additionally, there are checks performed on allowable responses precluding inappropriate data inputs driving an unusable output. It allows a large amount of user flexibility in tool selection. For example, the user could use SEER-SEM for the software estimation, and could use Price-H for the hardware estimation and could also augment with user-defined Training and Technical Documentation Cost Estimating Relationships (CER). This flexibility is valuable and necessary for elements that are not found in the AFTOC database (such as commercial equipments).

ICE provides the user the ability to input their own database (currently done manually, although it would be easy to provide for an import mechanism) of parts if they are not in AFTOC. In 2002, ICE had been deployed across the entire Air Force cost estimating function.

4.6.3.2 UM MOCA

In November 2001, University of Maryland Professor Peter Sandborn, Ph.D. and two graduate students (Dorethea Labogin and Arindam Goswami) hosted Mr. Butch Ardis (then the Air Force Avionics Chief Architect) and Tom Herald at College Park, MD for a technical exchange regarding the Mitigation of Obsolescence Cost Analysis (MOCA) capabilities and future opportunities. The following paragraphs highlight some of the results from that exchange and the subsequent technical review.

MOCA offers two fundamental ways of calculating cost numbers for the assessments. It has an internal set of formulas that calculate "MOCA Dollars." This cost represents only a portion of the Total Ownership Costs (TOC) and should be used for trade study comparisons only, and would not be appropriate for preparing a LifeCycle Costing Assessment. However, MOCA can be consistently applied to any input bill of materials, and as such provides a trustworthy Cost as an Independent Variable (CAIV) trade-study analysis.

MOCA also has the ability to leverage the Price Systems tool suite for preparing the cost analysis (Price H and Price HL). This link allows for MOCA to send data to Price, and Price provides the resulting data back to MOCA. The optimization engine appears to perform an iterative set of analyses to provide the user with a concise output graph that highlights the considered alternatives, and their placement on a scale of affordability (i.e. CAIV analysis). Therefore, MOCA is very strong and "user intuitive" with component-level analysis of an electronics board assembly.

4.7 Technical Interchange Meetings

Many discussions and technical interchange meetings were held between LM personnel, and the ACME/PO tool and technology developers. Some of these meetings are highlighted below.

4.7.1 2000

Manufacturers were visited for software reviews and discussions concerning their availability and application. Additional meetings were scheduled to take advantage of synergies between the providers. Non-Disclosure Agreements were sent out and reviewed to ensure they were completed, and principal Points-Of-Contact (POC) were identified for all of the ACME Technology / Tool vendors. Meetings held this year included:

2/10	Aspect Coordination Meeting (Mountain View, CA)
3/7	Boeing Flexible Foundry / VP Technologies / LMC Pilot Programs Technical Interchange Meeting (Boeing)
4/11	Aspect Focus Group Meeting / Conference Call (Dallas)
5/2	LMC / VP Technologies Technical Interchange Meeting (Orlando)
5/14	LMCS / VP Technologies ASIC IR&D and 1750 microprocessor evaluation (Johnson City)

5/24	LMC / Northrop / VP Technologies TIM (Baltimore)
6/7	Litton TASC Final Program Review (Dayton)
7/18-20	Litton Tool training (Dayton)
7/14	Information Systems' COMMAND Database Review (Orlando)
7/19	Aeronautics Application of Litton TASC Tool for C5 (Marietta)
8/8-10	Litton TASC Tool Training (Dayton)
8/9	VP Technologies Overview and Roadmapping Session (Orlando)
8/17	UCF Engineering Senior Design Project Meeting (Orlando)
8/25	Engine Control Service Center Data Collection TIM (Fort Wayne)
9/5-7	IWTA Coordination Meetings (Johnson City, Dallas)
9/13-14	Orlando / VP Technologies Roadmap Meeting (Atlanta)
10/10	Stan Arthur Briefing on Aging Aircraft and POMTT (Orlando)
10/11	ILI Demo / Review (Orlando)
10/23	Averstar Program Plan Informal Review (Orlando)
10/27	JASSM / Arrowhead / F-22 MLD TIM for VP Technologies Pilot (Orlando)
11/1-2	Aspect CSM / LCM Training (Dallas)

Presentation of some of the tools was also provided to internal management and program leadership.

4.7.2 2001

Technical discussions, training, and interchange meetings held during this year are summarized as follows:

1/8	TRW Technical Interchange Meeting (Dayton)
1/25	VP Technologies / F-22 MLD Teleconference
1/30	F-16 / EPOI Collaboration Meeting (Ft. Worth)
2/1	Aging Aircraft SPO Presentation (Ft. Worth)
2/5	Engineering Systems / Rosetta Overview (Orlando)
2/6	Lockheed Martin NE&SS Process Overview (Manassas)
2/8	F-22 / Litton Demo & VP TIM (Marietta)
2/28-3/1	i2 LCM Users Group Meeting (Dallas)
3/8	POMTT Overview Presentation (Ft. Worth)
3/12-15	CSM / PDM Orlando/Dallas Joint Application Development (JAD) (Orlando)
3/21	BAE System Controls POMTT / IRAD Program Review (Johnson City)
3/28	PEO Tactical Missiles Meeting (Orlando)
4/11-12	Orlando / Dallas IRAD Reviews (NetMeeting)

5/1 -3	CSM / DIACS Migration and LCM Integration (Dallas)
6/14	Rosetta / Vectorgen Overview (Netmeeting)
7/10-7/11	EPI Commercial Tech. Insertion Working Group (CTI-WG) (Moorestown)
7/23	VP Technologies SOW (Telecon)
7/26	CTI-WG Telecon
8/14	3rd Quarter Program Review with AFRL at Dayton Field Office
8/28-8/29	RADSS Training and Model Development (Dallas)
9/4	VP Technologies Shadow Pilot Bid Negotiations (Marietta)
9/12	RADSS Model Development Review Meeting (Dayton)
10/8	RADSS Complex Low Level Model Development Telecon
10/15	RADSS Complex Low Level Model Development Follow-up Telecon
10/16	EPI Commercial Technology Insertion - Working Group Telecon
10/22	VP Technologies Shadow Pilot Design Review (Atlanta)
10/29-30	RADSS Model Development Meeting (Dallas)
10/31-11/1	RADSS Tool Training (Dallas)
11/5-7	CTI-WG/Electrical Subcouncil Meeting (Dallas)
11/8	CSM ROI Teleconference
11/15	VP Technology/Longbow ASIC Pilot Review (Atlanta)
11/16	Low Level RADSS Model Teleconference
12/10	December RADSS Flow Model Development Netmeetings (Orlando - Dallas)
12/12	VP Soft Pilot Progress Review (Atlanta)

The collection, coordination, and dissemination of information continued. Publication of outlines for potential pilot programs was being communicated with the tool developers. For example, POMTT met with Litton, i2, and TRW (and their sub-contractors) on numerous occasions to discuss and define pilot requirements. Additional meetings provided advanced training in the use of the Litton TASC tool, a demo of i2's LifeCycle Module, and a demo of TRW's SLDL language and EDAptive tool.

Work was begun in the areas of Best Practices and new Corporate Procedures through involvement with the Commercial Technology Insertion – Working Group (CTI-WG). POMTT created and provided to the Working Group their first deliverable which is a Lexicon of Obsolescence and Commercial Technology terms and definitions (see Figure 4.3) which, since being posted on the LMC-Internal Working Group's web page, has proven to be very useful since nothing similar was available either internally or in industry.

Lexicon – Revision 1

AVIONICS

Electrical and electronic systems and devices used in aviation, missilery, and astronautics. (contraction of aviation and electronics)

(http://jcs.mil/htdocs/teinfo/gtem/ewglos.htm) (Department of Defense Joint Program Office for Test and Evaluation (JPO-T&E).

BRASSBOARD CONFIGURATION

An experimental device (or group of devices) used to determine feasibility and to develop technical and operational data. It normally is a model sufficiently hardened for use outside of laboratory environments to demonstrate the technical and operational principles of immediate interest. It may resemble the end item, but is not intended for use as the end item.

(http://jcs.mil/htdocs/teinfo/gtem/ewglos.htm) (Department of Defense Joint Program Office for Test and Evaluation (JPO-T&E).

Figure 4.3 – Lexicon Excerpt

POMTT also created a table that lists tools that can be used for Obsolescence Management and Commercial Technology Insertion (see Table 4.1).

Table 4.1 – Tool Summary Excerpt

Obsolescence/Commercial Technology/Component Assessment Tools

Electronic Design Methodology Tools

SLDL (System Level Description Language) – *EDAptive Computing*

Company Link - http://www.edaptive.com
Description – System Level Description Language (SLDL) consists of two system level design software tools that expect and facilitate re-engineering over a system's entire lifecycle. Synopsys' Behavioral Product Re-engineering (BPR) tool is based upon their VHDL behavioral synthesis CAD environment (Behavioral Compiler) and integrated with Synopsys' Design Environment (SDE). The BPR tool synthesizes RTL and VITAL level simulation models directly from the SLDL. A Design Verification Test Generation Tool (DVTG) was developed by the University of Kansas and has been commercialized by EDAptive Computing, Inc. The tool partially automates the test development process by generating test vectors for WAVES VHDL Test Benches from formal product requirement specifications in SLDL.
Contact – Dr. Praveen Chawla (pchawla@edaptive.com)

VP Technologies

Company Link - http://www.vptinc.com
Description – VP has developed software utilities and methodologies that are used to automate the re-engineering and new design process to create electrical models in VHDL. They have experience in creating simulatable and synthesizable models for both board assemblies and individual ICs, including microprocessors, and have developed cost-effective and efficient component and board level methodologies to maintain and upgrade current and future electronics systems. Their use of existing commercial tools and component model libraries facilitate virtual prototyping services and virtual libraries to automate the process of building virtual prototypes. VP's tools and methodologies can be used to enable design recovery of an existing design with varying levels of supporting data, design re-engineering at multiple levels of abstraction, parts design and selection, component model timing and function verifications, and model generation and synthesis.
Contact – Dr. Vijay Madisetti (vkm@vptinc.com)

Overall, there are seven tools: (1) Cost Methodology, (2) Electronic Design Methodology, (3) Design Support, (4) Databases, (5) Obsolescence Prediction, (6) Reliability Analysis, and (7) Design to Value. Table 4.1 includes both POMTT and ACME tools as well as those internally developed by LMC, gives a brief description of the tool, its benefits, and disadvantages; and provides application data and key user and developer contacts.

Initial meetings were held between Lockheed Martin Missiles and Fire Control - Dallas (LMM&FC-D) and EDAptive to discuss Rosetta and Vectorgen. Additional exchanges continued internally during the quarter as Dallas further evaluated the tools and defined potential pilot projects. For example, the PAC 3 program provided VHDL specifications and test vectors to use while evaluating the SLDL approach and both the EDAptive VectorGen™ and Synopsys BPR tools. Further meetings were planned to establish non-disclosure agreements and explore translation of program VHDL specifications to SLDL format.

At BAE SYSTEMS Controls, Kevin Hill brought together Greg Cappelli and Phil Ellis of UTMC, and Dr. Vijay Madisetti of VP Technologies (via telecom) to discuss porting of commercial chips to a radiation tolerant process. In addition to the radiation tolerant initiative, UTMC agreed to evaluate developing MIL-STD-1750A capability using IP from VP Technology.

More advanced meetings were held at each site for program and functional management. For example, in Dallas, the MLRS program was given an overview of the emerging tools and, as a result, MLRS and POMTT agreed to collaborate on an improved approach for managing change for MLRS and participation in upcoming demos and training.

4.7.3 2002

Of significant note during 2002 was the continued development and progress of the RADSS Complex Part Model through regularly scheduled Netmeetings. These focused Dallas and Orlando Subject Matter Experts (SME) on expanding Orlando's obsolescence flowchart and integrating Dallas' requirements to develop a single process for both.

Additional meetings and discussions with the SLDL tool developers at EDAptive and the University of Kansas were held (as summarized below0 and non-disclosure agreements were established.

1/8, 16	January RADSS Flow Model Development Netmeetings (Orlando - Dallas)
1/9	CSM Integration Team Netmeeting (Orlando - Dallas)
1/14	LCM Assessment Meeting
1/16	CTI-WG Telecon
2/5,13,20,27	February RADSS Flow Model Development Netmeetings (Orlando - Dallas)

2/7	Ft. Worth Telecon
2/8	CSM Netmeeting (Orlando - Dallas)
3/4	Dallas DIACS/CSM Integration Telecon (Orlando/Dallas)
3/6	RADSS Obsolescence Flow Model Development Netmeeting (Orlando/Dallas)
3/6	CSM Requirements Netmeeting (Orlando/Dallas)
3/13	RADSS Obsolescence Flow Model Development Netmeeting (Orlando/Dallas)
4/2	CSM Migration Netmeeting (Orlando/Dallas)
4/4, 4/17	Obsolescence Flow Model Development Netmeeting (Orlando/Dallas)
4/11, 4/25	M&FC-Dallas Processor Emulation Pilot Teleconference
4/23-25	Obsolescence Flow Model Development Meeting (Dallas)
4/30	CSM User Training (Orlando)
5/2	Cost Methodology Program Plan Review (LMNE&SS-Manassas)
5/6	CTI-WG Netmeeting (Moorestown)
6/3	Northrop Grumman Metrics Coordination Meeting (Baltimore)
6/6	EPOI Iteration 1 Overview Meeting & TIM for ICE (FTI-Dayton)
7/10	CTI-WG Telecon
7/25	AFRL POMTT 2nd Quarter Program Review
8/7-8	RADSS model development (Orlando)
8/29	BAE GT Pilot Meeting (Atlanta)
9/10	Brig. General Sheridan Briefing (Warren AFB)
9/17-18	RADSS Training (Dayton, OH)
9/26	VP Technologies/IRST Pilot Evaluation Meeting
9/26-27	Northrop Grumman Program Review, POET Demo, & Metric Review
10/8	R2T2 Advancement Development Telecon
10/28	Orlando/Dallas CSM Obsolescence Requirements Telecon
11/5	CTI Working Group Meeting and Telecon
11/9	Dr. Sandborn / Butch Ardis Technical Overview
11/18	Orlando/Dallas CSM Obsolescence Requirements Telecon
11/20-21	LM Aero R2T2 Briefing
11/27	Management of Commercial Technologies Assessment
12/2	MOCA for COTS Bill of Materials Telecon
12/18	POMTT Program Review (Orlando)

The majority of these meetings were in support of pilot definition and ongoing model development. Additional work continued in the areas of best practices and new corporate procedures through involvement with the Commercial Technology Insertion – Working Group (CTI-WG). For example, the first revision to the new CTI-WG Lexicon was also posted at the Lockheed Martin internal CTI-WG web site. POMTT continued progress on the Tools Database and Evaluation Capability that identified commercially available obsolescence, decision support, analysis, and design tools that could be used to solve component, commercial technology, obsolescence, and design decisions.

A key technical interchange was a conference call held with VP Technologies, AFRL MANTECH, the F-16 program office, and the Aeronautical Enterprise SPO at Wright-Patterson AFB. During the conference Matt Brown (Hill AFB) reiterated the need for MIL-STD-1750 processors and support chips for the F-16 but that utilization rates were very low. The teleconference revealed that a pilot would likely focus on support chips and VP indicated that Boeing is also interested in the 1750 for support of the F-15.

Dallas participated in an i2 Upgrade Workshop at i2 Technology headquarters in Dallas on August 13. The workshop focused on upgrading existing component management systems to i2's Supplier Relationship Management (SRM). At the meeting, i2 presented their financial status to mitigate concern about their business future and have reorganized their sales approach.

In another meeting, BAE's Tom Cirillo and Rich Wisniewski met with Georgia Tech personnel to present BAE's PEM failure data on August 29. In the meeting, Georgia Tech presented their progress on development of physics-of-failure based mechanical analysis models and their application on commercial Ball-Grid-Arrays (BGA). These discussions initially led to a technology pilot for Ball Grid Array (BGA) failure life analysis of commercial parts and its eventual upgrade to a production pilot.

4.7.4 2003

Most meetings held in 2003 were to support pilot setup, installation, and application. Some others, however, were to explore further applications or extensions of the tools. For example, two demonstrations of the Obsolescence Decision Tool were given – one for AFRL (Monica Poelking), and one for Missiles and Fire Control Product Development Vice President, Dutch Shoffner. As a result of the AFRL demo, a white paper was provided to propose an application of the ODT for use at the Air Force's Logistics and Systems Centers.

Dallas participated in a MLRS Program Obsolescence Working Group (OWG) meeting that included presentations by obsolescence industry companies MINCO, CPU Technologies, and Rochester Electronics. MINCO and Rochester purchase discontinued production residual die and wafers and package them to QML requirements. CPU Tech specializes in retargeting complex legacy systems to ASICs with virtual prototyping. The Defense Supply Center – Columbus (DSCC) also attended the meeting but indicated that they do not consider many "discontinued" devices obsolete since they maintain adequate stock, or can make a bridge buy, to meet service needs. DSCC actively works with the aftermarket suppliers to ensure devices are available as needed to support older weapons systems. These interchanges were held during 2003:

1/16	SCOC SRM Software Installation Assessment (Orlando)
1/16	i2/JASSM Pilot Technical Support Negotiation Teleconference
1/29-30	Obsolescence Decision Tool Demo (Dayton)
1/30	i2/JASSM Pilot Kickoff Meeting (Orlando)
2/5	ODT Demonstration for Dutch Shoffner (Orlando)
2/6	Bayesian Decision Networks Plus-Up Meeting (Dayton)
2/6	FTI Program Review (Dayton)
2/20	AOA Pilot Kickoff Teleconference
2/20	AOA Pilot PartsExpert Demonstration (Dallas)
3/6	JASSM Metric Evaluations (Orlando)
4/7-10	RADSS Pilot Completion (Dayton)
4/10	POMTT 1st Quarter Review (Orlando)
4/14-16	i2 Software Installation Support (Orlando)
4/29	Dr. Winsor POMTT Program Review (Orlando)
5-6	i2 User & System Administrator Training (Orlando)
5-6	Electrical Subcouncil/CTI-WG Meeting/ODT Demo (Akron)
6/9	JASSM Life Cycle Manager Evaluation Kickoff (Orlando)
6/24	F/A-22 / AOA Coordination (Dallas)
6/25, 8/11	Tool Evaluation Database Telecon (EPI)
7/16	CTI-WG Telecon
8/12	POMTT Quarterly Review (Johnson City, NY)
9/3	CTI-WG Face-to-Face Planning Session
10/3	POMTT IRAD Technical Presentation (Orlando)
10/10	EPI Site Leaders Meeting (Orlando)
10/15	CTI-WG Telecon
10/23	CTI-WG Telecon
10/28	MTADS/MOCA Pilot Briefing (Orlando)
11/10-11	CTI-WG Face-to-Face (Orlando)
11/19	CTI-WG Telecon
12/ 10	POMTT Year End Program Review. (Dallas)
12/16	MOCA Pilot Results Presentation (Orlando)

Meetings with other sites, such as Lockheed Martin Aeronautics Company – Marietta's Chris Vachtsevanos (Parts Obsolescence Manager for the C-130J program), were significantly beneficial since they provide insight into tools and processes needed for these programs. Several program's representatives participated in the meetings and a few also participated in pilots by providing program data for the evaluations.

Work continued with the CTI Process Group as POMTT demonstrated ODT at a face-to-face meeting held in Akron, Ohio. The group was very receptive and William Dreisbach (EPI member and facilitator for the CTW-WG) agreed to be involved in discussions to determine if and when ODT can be hosted on EPI's web site. Also, the new Obsolescence Management Guidelines document was completed this year.

4.7.5 2004

As the program completed the pilots, discussions and technical interchanges continued to be held this year:

2/17	TRENT / POMTT Integration Telecon
2/19	Boeing / Hellfire Retarget Telecon
3/10	POMTT / C-5 Program Discussion Meeting
5/18	1st Quarter Program Review

Several noteworthy meetings were related to educating and transitioning the experiences and lessons learned from POMTT to other Lockheed Martin sites and programs. For example: discussions were held with Greg Bricker, Director of Customer Requirements for the C-5 program at Lockheed Martin Aeronautics in Marietta, GA. He is also reviewing the future needs of C-5 and other Aeronautics programs and developing approaches to solve common issues. Also, at the 1st Quarter Program Review held in May, Jay Gurecki attended from NASA, Cape Canaveral. Jay is the Obsolescence Manager responsible for the Shuttle Fleet and the Space Station. He was also very interested and requested support by the POMTT team.

An additional request was also received from Calvin Mack, Program Manager of Logistics at Lockheed Martin's Air Logistics Center in Greenville, SC. Calvin is working to bring together the logistics requirements from the various Aeronautics programs including C-5 and C-130 and had heard about POMTT through involvement in the Aging Aircraft IPT Proposal. The program responded by providing information about the tools and technologies that were evaluated.

The Engineering Process Improvement Center released Revision 1 of EPI 110-05 - Obsolescence Management Plan Guidelines. This document is a direct result of the POMTT Program and, although adopted by the Commercial Technology Insertion (CTI) Process Group, was created by POMTT to define corporate guidelines for proactive obsolescence management plans. The Guidelines promote a set of detailed solutions (including tools, technologies, and design approaches), web links (internal and external LMC), and examples, one of which has already been put to use on the Hellfire program (Obsolescence Management Survey Form). These resources and solutions can be integrated into proposal and technical reviews, and any of the program planning, materiel selection, procurement, and other related processes across Lockheed Martin.

A great deal of other work and training is being performed through CTI-WG. The Tool Evaluation and Benchmark Database (TED) development effort that was led by POMTT primarily to capture the program's evaluation data has now been published for company use. It is available through Lockheed Martin's Engineering Process Improvement (EPI) Center and after only two months, captured more than 40 discrete tool evaluations.

4.8 Conferences, Workshops, and Symposiums

The POMTT program provided support to a number of national and international conferences and symposiums through attendance, submission of abstracts, and presentation of papers. Team members also participated in panel sessions, working groups, and user groups.

Participation and presentation at these conferences publicizes and encourages the use of POMTT tools throughout Lockheed Martin and the aerospace industry. They also help the program educate and train Lockheed Martin, military, and industry personnel on the benefits of newly developed obsolescence management tools and practices.

4.8.1 2000

The following Conference and Symposium meetings for year 2000 are summarized below:

1/30-2/02	CTI Commercialization Conference (Los Angeles)
4/4-5	EPOI Workshop at Northrop Grumman (Baltimore)
4/17-18	COTSCON (Washington, DC)
5/9-11	National Aerospace Systems and Technology Conference (Dayton)
5/13-17	4th Intl. NATO Maintenance and Supply Agency (NAMSA) DMSMS Conference (Luxembourg)
8/8-9	Avionics Roadmap 2000 Conference (CALCE Center - University of Maryland)
8/21-24	DoD DMSMS Conference (Jacksonville)
9/25-27	2000 Mission Critical Enterprise Systems Symposium (Orlando)
10/16-18	AIA Product Support Conference (Colorado Springs)
10/18-20	VIUF Conference (Orlando)
10/24-26	Aspect Users Conference (Orlando)
11/8-9	Commercial Technology for the Warfighter Conference (Virginia)
11/27-30	DMC Conference (Tampa)

Lockheed Martin provided support to the defense industry, Aging Aircraft, and other initiatives through attendance and presentations given to various DoD and industry workshops, and conferences. For example, support of the EPOI workshops continued throughout the life of the program with a status of the POMTT effort provided.

A paper detailing the POMTT program, tools, and potential pilots was presented to the 4th International NATO Maintenance and Supply Agency (NAMSA) DMSMS

Conference held in Capellen, Luxembourg. NATO's goal is the development of a Logistics Stock Exchange Program to bring together NATO users and their systems manufacturers and reduce costs through requirements aggregation and management, thereby minimizing the potential impact from obsolescence on NATO's international and U.S. developed systems such as AWACS and F-15.

POMTT attended the VIUF Conference on VHDL Design in Orlando where VP Technologies presented a paper on their tools and overall approach to parts obsolescence, and a second paper that provided additional detail on their methodology. TRW also attended and presented a paper that detailed their work on the test vector generation tool (DVTG).

POMTT attended the "Commercial Technology for the Warfighter Conference" which was held in Virginia. This conference was instrumental in understanding the roadmaps for future investment as related to the Aging Avionics strategy, particularly in light of the establishment of the new SPO for Aging Aircraft in December 2000.

4.8.2 2001

In 2001, POMTT attended and presented at a number of DoD and industry workshops and conferences including:

1/31-2/1	DoD DMSMS Teaming Group Meeting (Dallas)
2/13-16	Commercial Technology Insertion Conference (Los Angeles)
2/28-3/1	i2 LCM Users Group Meeting (Dallas)
4/24-25	EPOI Workshop (Georgia Tech - Atlanta)
5/1-2	DoD DMSMS Teaming Group Meeting (Folsom, CA)
5/3	DoD DMSMS Workshop (Folsom, CA)
5/15-17	NASTC 2001 Conference (Dayton)
6/18-6/22	Design Automation Conference (Las Vegas)
7/12	COTS Summit (Moorestown)
7/17-7/19	DMEA DMSMS Teaming Group Meeting (Danvers, MA)
8/22	Avionics Affordability Best Value Evaluation Methodology Mtg. (Dayton)
9/11	EPOI Workshop (Dayton)
11/1	Best Value Industry Day No. 2 (ASC/AA) (Dayton)
12/11	AFRL/Boeing Industry Workshop (St. Louis)
12/11	Dual Use Science & Technology Conference (St. Louis)

LMC and POMTT provided inputs to the Aging Aircraft System Program Office RFI Concept call for 3-year (max) projects that could begin in 2004 targeted at transitioning technologies to benefit the sustainment community, specifically subsystems and avionics/electronics.

The program also presented a summary of POMTT's progress at the Commercial Technology Insertion Conference held in Los Angeles, CA. The purpose was to inform the military development community of the program and its evaluation of the commercial tools being developed.

Missile and Fire Control Orlando's Jeff Brian attended the Design Automation Conference in Las Vegas, specifically EDAptive's presentation of the VectorGen™ and associated tools. EDAptive used the conference to officially commercialize the TRW-contracted System Level Design Language (SLDL) through development of several tools.

Bob Jeffers attended an Industry Day Briefing at AFRL, Dayton, which was sponsored by the Aging Aircraft SPO. The Industry Day briefing centered on developing a "Best Value Methodology" for Avionics Viability and developing an approach for an "Avionics Viability Index (VI)" that will be used as a new metric when evaluating industry proposals for aircraft avionics. This is a part of the "Spiral Approach" to have industry and the government work together as a team.

Dallas POMTT personnel attended the Engineering Process Improvement Center (EPIC) sponsored "Delivering Results in the 21st Century - Mission Success" conference in Orlando (also known as the Joint Symposium 2001, JS01 Conference).

Lockheed Martin - Dallas presented two papers at the 2001 Military and Aerospace COTS Conference on 17 August titled "Integrating Emerging Commercial Technologies for Obsolescence Management" and "PROMPT: Part Replacement and Obsolescence Mitigation Prediction Tools".

Unfortunately, in late 2001, several Conferences and Symposiums that POMTT was presenting at or planning to attend were cancelled, postponed, or not attended due to the terrorist attacks. For example, the 5th International Commercialization of Military and Space Electronics Conference and Exhibition which was being held in Nice, France was not attended and the paper was withdrawn since travel restrictions at LMCO prevented attendance. Also, Lockheed Martin's own Mission Critical Enterprise Systems Symposium (MCES) that was scheduled to be held in October was cancelled and the Defense Manufacturing Conference (DMC) 2001 in Las Vegas on November 26 – 29 also was not attended due to September 11th travel restrictions.

4.8.3 <u>2002</u>

POMTT continues to participate and represent the program at various DoD and industry workshops, conferences, and other meetings. Those attended in 2002 were:

1/29-31	DoD Teaming Group Meeting (Washington)
2/11-14	CMSE Commercial Technology Insertion Conference (Los Angeles)
3/25	EPOI Meeting and Presentation (New Orleans)
3/26-28	DoD DMSMS Conference (New Orleans)
4/16-19	Mission Critical Enterprise Systems Conference (Orlando)
5/13-16	i2 Planet Conference (Las Vegas)

5/13-16	NASTC Conference (Dayton)
6/4-6	DMSMS Teaming Group Meeting (Pax River)
6/11-13	Design Automation Conference (New Orleans)
8/7-9	MIL Aerospace Avionics COTS Conference (San Diego)
8/13-14	NAVSEA DMSMS Workshop (Oxnard)
9/16-19	6th Joint FAA / DoD / NASA Aging Aircraft Conference
9/21-24	NDIA Systems Engineering Conference.
9/24-26	DoD DMSMS Teaming Group Meeting
12/2-5	DMC 2002

At the June 4-6 DMSMS Teaming Group Meeting in PAX River, MD a report on the activities of their Materials Working Group was presented. The purpose of the group is to develop and maintain a process that will provide early warning for obsolescence and identify common weapon systems or product users. Although the scope of obsolete materials to be covered has not yet been identified, the group has formed a test case of several chemicals:

a. Vinyl alcohol acetate resin (VAAR) (Bakelite resin)
b. Mil grade black powder
c. Dinitrotoluene (DNT)
d. Celluose/Nitrocelluose

Although not directly related to the EPOI tools, meetings like these must be taken into account for each of the tools evaluated to determine its applicability to LMC.

The POMTT program attended the 2002 Military & Aerospace / Avionics Conference in San Diego, CA on August 7 - 9 and presented a paper titled the "The End of Obsolescence?" The paper was submitted by Dave Darling (LMMFC-Orlando) and co-authored by Jim Houston (LMAC-Ft. Worth) and Tom Herald (LMNE&SS-Manassas). In it, the team outlined Lockheed Martin's efforts to bring all of the corporation's discrete operating divisions together to end obsolescence through participation in, and coordinated application of, internal and external initiatives such as the POMTT program, EPOI, LMC's EPI Center, and advanced developments such as Technology Insertion, Cost Methodologies, and Technology Roadmapping. The three also participated in a Panel Session on industry efforts and activities in the area of obsolescence management and mitigation.

In May, Dallas personnel attended the GEIA Avionics Process Management Committee (APMC) meeting held at Lockheed Martin Aeronautics facilities in Fort Worth. The committee is preparing several standards one of which is the COTS Assembly Management Process (CAMP) that can be used as a guide by aerospace and defense companies. Lockheed Martin is a member of the GEIA and many LMC sites participate in these efforts.

The POMTT program supported the 6th Joint FAA / DoD / NASA Aging Aircraft Conference in San Francisco, CA on September 16-19. Bob Jeffers presented a paper titled "Emerging Technologies for Electronic Parts Obsolescence Management". On December 2-5 Bob Jeffers and Dave Darling co-presented a paper titled “Emerging Trends in Obsolescence Management” at the 2002 Defense Manufacturing Conference held in Dallas, Texas.

4.8.4 2003

In 2003, the POMTT program continued its participation in various workshops and conferences as follows:

1/21-23	DoD DMSMS Teaming Group Meeting (Tucson, AZ)
2/10-13	Commercialization of Military and Space Electronics Conference (Los Angeles)
5/12-15	i2 Planet Conference (Las Vegas)
5/13-15	NASTC Conference (Dayton)
8/13	Technology Roadmapping Workshop (Dallas)
8/19-21	DMSMS 2003 Conference (San Diego)
9/8-11	Aging Aircraft Conference (New Orleans)
10/8-10	Mission Critical Enterprise Systems Conference (Orlando)
10/13-17	i2 Technologies' Directions User's Group Meeting (Orlando)
11/17-20	AIAA Conference (Denver)
12/1-4	Defense Manufacturing Conference (Washington DC)

Dave Darling and Bob Jeffers each presented papers to the 2003 Commercialization of Military and Space Electronics Conference in Los Angeles, CA covering the POMTT program and its application of obsolescence management tools.

The program attended the DoD Diminishing Manufacturing Suppliers and Material Sources Working Group Meeting the week of January 21st. This is the Government's key vehicle for day-to-day, multi-service, program obsolescence support.

Dave Darling represented Lockheed Martin at a recent Government Electronics and Information Technology Association's (GEIA) Aerospace Process Management Committee meeting in Tucson, AZ. Greg Saunders, Director of the DoD's Standardization Office was in attendance. The Institute performs advanced testing and collection of environmental data, radiation effects, and structural loads in flight vehicles and avionics systems.

POMTT participated at the 2003 DMSMS Conference in San Diego, CA, August 18-21 where Dave Darling served as a Session Moderator. Of particular note, this year's conference provided two special sessions for EPOI activities, the second of which was all Lockheed Martin/BAE POMTT related presentations.

Dallas’ Doug Fuller and Trey Fixico delivered presentations at the August DMSMS 2003 Conference on "Automated Obsolescence Assessment (AOA), Integrating the Aerospace Enterprise" and “System Level Test Automation (SLTA), Expediting

Obsolescence-Induced Redesign" respectively. EDAptive also supported the Lockheed Martin presentation during the DMSMS Conference by providing a live VectorGen™ demo.

Dave Darling attended the 2003 Mission Critical Enterprise Systems Conference and presented a paper entitled "An Enterprise Approach for Obsolescence Decisions". He also provided an internal presentation as part of the bi-weekly IRAD reviews that resulted in several program inquiries concerning ODT and the Georgia Tech Ball Grid Array reliability modeling.

Bill Furlong attended the i2 Directions Conference in Orlando along with Steve Burge (M&FC-Dallas), who is the Vice Chairman of the i2 Users Group. The Directions Conference is i2's user-focused venue and included presentations from multiple industries that highlight the application of i2 products and their performance. Of note, it was that at this meeting that POMTT first learned of i2's intention to cease support for the ASPECT based version of the software. Also, Raytheon and Honeywell stated that they were installing SRM and Northrop Grumman and Boeing have both expressed intentions to do so as well. Issues like these show that these conferences continue to be sources of information as well as dissemination.

Doug Fuller presented two papers, titled "Automated Obsolescence Assessment (AOA), Integrating the Aerospace Enterprise" and "System Level Test Automation (SLTA), Expediting Obsolescence-Induced Redesign" at the DMSMS 2003 Conference in August. He also gave an updated AOA presentation at the Lockheed Martin Mission Critical Enterprise Systems (MCES) Symposium.

In November, Jamie Green and Dave Darling co-presented a paper at the American Institute of Aeronautics and Astronautics (AIAA) 3rd Aviation Technology, Integration, and Operations (ATIO) Technical Forum in Denver, CO. It focused on the use of ODT to educate and improve the obsolescence decision process at LMC.

4.8.5 <u>2004</u>

POMTT decreased its participation in DoD and industry conferences as the program wound down in 2004. Those attended were:

2/9-12	2004 Commercialization of Military & Space Electronics Conference & Exhibition (L.A.)
3/29-4/1	2004 CTMA Symposium (Atlanta)
4/27-29	i2 Planet Conference (San Diego)

The Commercial Technologies for Maintenance Activities (CTMA) was a new conference attended this year. CTMA is collaboration between the National Center for Manufacturing Sciences, its member companies, and the Department of Defense (DoD) and sponsors technology development, deployment and validation. The current focus is on the use of manufacturing technologies to reduce the costs associated with maintenance and rebuilding of weapons systems as an element of the overall DoD maintenance strategy. Obsolescence management is a key area and was the subject of several papers, one of which was presented by Bob Ernst, Program Manager for Obsolescence Management at NAVAIR Pax River, MD.

Three POMTT papers on completed projects were presented at the Commercialization of Military and Space Electronics Conference in Los Angeles. Dave Darling, Carolynn Amberntson, Caleb Santiago, and William Furlong presented the following papers:

- "Results of the Parts Obsolescence Management Transition Program at Lockheed Martin" (Dave Darling)
- "Establishing an Optimal DMSMS Resolution Matrix: Part-Level vs. Assembly-Level Solutions" (Carolynn Amberntson)
- "Results of an Electronic Parts Obsolescence Prediction Study Using i2 Technology's Supplier Relationship Manager Tool" (William Furlong and Caleb Santiago)

These presentations were provided in an "All-POMTT" session and generated discussions and several requests for additional information. Through these and other presentations Lockheed Martin is recognized as the industry leader in the application of obsolescence tools and technologies.

4.9 Subcontracts

During the term of the program, a series of subcontracts have been awarded to obtain services and tools for the evaluations. Several tool/technology providers were contracted to provide their products, support services, and training to ensure adequate completion of the pilot evaluations. These are detailed in the following sections.

4.9.1 VP Technologies

In early 2000, a subcontract for VP Technologies was initiated at M&FC-O to facilitate the installation of VP's tools in Orlando, and to support program pilot selection activities. Discussions about developing behavioral models, different processors, the engineering effort required during design trade studies, and processor standardization across Lockheed Martin were held and relied on VP's expertise in these areas. For example, the cost of a model of the PowerPC (G4) was estimated to be in excess of $600K, of which a majority would have to be provided by Lockheed Martin. For this investment, LMC would have received limited rights to the model under license to VP. VP was also considered as a source for a 1750 processor by BAE Systems Controls but this was cancelled when other manufacturers for the 1750 picked up the design.

A Longbow program ASIC that was being redesigned as an FPGA was identified as a potential pilot and VP was included in the bidders list. Although VP's bid was not selected, a pilot project was established and funded by POMTT to "shadow" the design of the bid winner. This technology pilot required VP to use the same data and schedule requirements as the contract winner and POMTT would collect cost, manpower, and performance data which would be used to help justify or eliminate any follow-on pilots. In 2003, the VP subcontract was completed as funds were being directed to pilots that had been adopted by programs and were approved by AFRL.

4.9.2 Northrop Grumman Information Technologies (NGIT) (Litton TASC)

Missiles and Fire Control - Orlando established a subcontract with Northrop Grumman Information Technologies (formerly Litton TASC) for technical support and training in the use of the RADSS 2000 tool. LMM&FC-Dallas defined and placed a subcontract with NGIT for three training and modeling sessions on the RADSS tool at the Missiles and Fire Control - Dallas' facilities.

Orlando also investigated a follow-on subcontract with TASC to continue model development of the Low Level Complex Parts model for the first quarter of 2002. As part of the Complex Flow Model development, Missiles and Fire Control – Orlando completed a follow-on subcontract with Northrop Grumman Information Technologies to provide additional training and consulting support. Under the contract Northrop Grumman provided technical support for creation of a complex part decision and input into the RADSS tool. The overall model was considered as a method to provide a templated approach to the review and selection of day-to-day obsolescence solutions. The approach would establish a defined procedure, analysis, and detailed solution set and should be applicable across all programs, sites and users. Several tasks are defined in the SOW and are summarized as follows:

Task 1 -- Review the basic rules and software of the RADSS tool. Expand materials and documentation on the use of the RADSS structured decision modeling process and the RADSS tool prior to sessions.

Task 2 -- Conduct two days of review, training, and support activity divided into two, one-day sessions intended to assist Lockheed Martin in further development of the Complex Part Model for Obsolescence Decisions. Review, train, and support the Lockheed Martin implementation team in the development and refinement of the decision model.

Session "A" will be the review and introduction of the Complex Part Model into the RADSS software. Brainstorm on the decision model and its decision criteria, weighting, cost/resource attributes, solution alternatives, classification schemes and scenarios for typical users.

Session "B" will focus on finalizing the model, collecting and entering data, and applying the model to typical scenarios and decisions. Preliminary testing of the model after its development and implementation into the RADSS software will be performed at the end of the initial model development (prior to the model's use on a specific program's problem).

Task 3 -- Support model use and development via informal interactions (4-8 teleconferences) before, during, and after Task 2 Reviews, to work specific problem issues.

Task 4 -- Provide a Technical Report on the development process of the model, its effectiveness, usability, and usefulness, and a financial status report.

4.9.3 Boeing

Missiles and Fire Control - Orlando established a $50K subcontract with Boeing's Small Scale Electronics Division (SSED) for a formal feasibility study to determine the best approach for redesigning the existing Predator Quartz Rate Sensor (QRS) design. The redesign analyzed taking the ASIC from the current BiCMOS technology to a lower cost or greater performance CMOS process.

4.9.4 Georgia Tech

BAE's Advanced Packaging Engineering established a subcontract with Georgia Tech to utilize GT Ball Grid Array Reliability Stress mode. Work began and was completed on schedule in 2003.

4.9.5 EDAptive

Dallas procured training to support the start of the SLTA Pilot from EDAptive and secured licenses to VectorGen. Dallas obtained training in Rosetta and VectorGen™ to initiate the SLTA Pilot as well as procuring a 1-year license for use of VectorGen™ during the SLTA Pilot.

4.9.6 i2 Technologies (Aspect Development)

Both Orlando and Dallas obtained licenses from i2 Technologies for use of their database tools. A no cost letter agreement was obtained from i2 to use Dallas' existing CSM system in the assessment of F/A-22's Bill-Of-Material (BOM) data for the AOA Pilot.

Orlando established three subcontracts with i2: one for a limited, six-month pilot evaluation software license, a second for training and assistance in installation of the SRM software, and the third for user training on the SRM tool. The second included two technical support persons from i2 Technologies and the third provided user and systems administrator training for participating program, Components Engineering, and IT Management personnel. This also provided Missiles and Fire Control an early understanding of SRM's advanced capabilities and new architecture.

Section 5

Obsolescence Tools and Methodologies Baseline

This section looks at the existing obsolescence management practices and approaches used at Lockheed Martin and BAE. It also provides insight into the cost of obsolescence management and resolution and discusses details concerning metrics that were used to estimate and measure the performance of the EPOI tools.

For example, at Lockheed Martin existing best practices and processes were limited in their inclusion of obsolescence. Some procedures did exist throughout the corporation but were discrete and uncoordinated. Of the existing processes and procedures found, many were primarily acting as a general requirement with little specific direction as to who, what, or where any obsolescence management would be performed. These were very loosely interpreted at times specifically for smaller programs with limited funding and contracts that did not require it. Additionally, there were no top-level requirement processes or guidelines for obsolescence management at the start of a project in either the industry or the Lockheed Martin Corporation. What was being done was a limited amount of technology analysis often performed by Research and Technology that was primarily focused on each site's unique area of expertise, and the disruptive technologies that could affect them.

Overall though, there were four overall existing approaches to obsolescence being used at Lockheed Martin and BAE. Three of these are: Mitigation, Prediction and Monitoring. Another approach that was widely used was "No Action", which is a valid response but will only be evaluated to determine the cost impact of no obsolescence management.

5.1 Mitigation

Mitigation is the reduction in impact through manipulation of the design or system planning and scheduling requirements. This was being performed on several programs at Lockheed martin and BAE, though with a limited amount of effort. This approach does not attempt to predict future obsolescence or provide a consistent level of monitoring. It is primarily a reactive response to obsolescence occurrences as discovered. A minimal level of effort is typically applied on a case-by-case basis. The purpose typically is to maintain production of the current system, reduce or eliminate any cost impacts, and minimize or ignore any potential redesigns wherever possible. This approach is normally applied to older programs that have little likelihood of being upgrades or that are planned to be replaced by an entirely new design. Although low in manpower and change costs, this approach can actually result in a significant cost impact or loss of sales if an unexpected obsolescence event emerges that stops production and proves too costly to solve. Also, the costs of potential replacement parts can increase exponentially after becoming obsolete and may make a potential solution untenable.

5.1.1 Monitoring

Monitoring is the managing of obsolescence by reviewing a design, periodically assessing specific items in the system's BOM, and working any solutions in a reactive mode. This initially reduces costs due to a lower level of effort. It typically requires some analytic tools such as a database and assessment service, but is less costly in the long run due to being able to preclude the higher cost of replacement parts before the part becomes unavailable. This approach is usually applied to programs in production that are undergoing a moderate amount of continual change, and where additional changes to component parts can be absorbed as part of the normal process.

5.1.2 Prediction

Prediction uses analytic processes to ascertain the performance, reliability, and life cycle of obsolescence sensitive parts in preparation for a new system's design, production, redesign, or integration. The output of the obsolescence analysis is used to facilitate more effective and less costly materiel order planning, stocking, technical insertion, technology refreshment, and product redesign. The approach uses an algorithm or service to estimate (usually within a specified time period) upcoming obsolescence of sensitive items based on their technology, characteristics, and performance history. This data is compiled and, when matched to the program's design and production schedule, can be used to perform system changes and redesigns as a normal part of the product's development and production. A risk factor must be assumed however, due to the potential inaccuracy of the predictive data. But these risks can be mitigated through validation of the prediction algorithm or application of additional data sources. The cost for this approach is higher than monitoring or mitigation but potentially eliminates all but a few unpredictable obsolescence events that must be expected.

5.2 Existing Tools

At Lockheed Martin, a number of tools existed that were used primarily in product design and management. Most of these did not address obsolescence.

5.2.1 LM Tools, Technologies, and Practices

As a system designer and integrator Lockheed Martin maintains a significant library of tools and processes. The most obvious of these are use for electronic and mechanical design however; many other tools exist for design, layout, testing, simulation, and analysis. These have been reviewed for applicability to obsolescence management and corporate adoption.

The primary tool used at Lockheed Martin Missiles and Fire Control – Orlando is Mentor which provides an electronics schematic capture and graphic layout capability. Mechanical Engineering uses Pro-E as their 3-D design tool while Systems Engineering uses several for analysis. VHDL and Verilog are used by the ASICS Design group to define and modify software code for ASICS and FPGA's. Planning uses Microsoft Process for design and production scheduling and planning while Logistics uses different tools, some in-house and some commercially available, depending on each program's contractual requirements. Finance and Cost Analysis use Microsoft Excel and Price Systems tools to calculate system and proposal costs. Unfortunately though, none of these tools provide support for obsolescence issues including decision support or data management.

5.2.2 Obsolescence Management

Lockheed Martin had established a couple of tools to use in obsolescence management, primarily in the area of databases and obsolescence monitoring. A number of programs used TacTech's obsolescence monitoring and prediction service which was procured through yearly licenses. This tool provides a summary report of a submitted BOM's parts for matching to the TacTech database, identification of the approximate level of technology used to create the part and its relative age in comparison to the marketplace, and identification of those items not matched or found that provided no information. These were provided through a site license but most programs used a single point of contact to submit and disseminate data. This person also performed the distribution and coordination of GIDEP Alerts to all of the programs.

A couple of programs had created their own obsolescence databases to track existing issues and establish a case history for the program. These were discrete and did not share data, current work in progress, or solutions. Therefore, there was a certain amount of duplication of effort as well as competition for remaining part inventories.

There were no allowances made for obsolescence in any of the costing efforts. The only potential inclusion of obsolescence solutions were made in planning through scheduled redesigns for design changes, producibility, and performance.

5.3 Existing Site and Corporate Practices

Almost all obsolescence was performed by Components Engineering on a program-by-program, contract requirement basis, or was not performed at all except on an occurrence-by-occurrence basis. Expertise was shared on a very limited basis due to the programs needs and the willingness of the personnel.

At the corporate level, Lockheed Martin established the Engineering Process Improvement (EPI) Program in 1989 to reduce the cost of engineering by developing and implementing state-of-the-art processes at the Lockheed Martin companies. The EPI Program gathered participation from the majority of companies within Lockheed Martin and established a Technical Operations Management Council (TOMC), five functional Subcouncils (Electrical, Engineering project Management, Mechanical, Software, and Systems), and over forty Working and Process Focus Groups. The TOMC is made up of senior and site Vice Presidents in areas of Technical Operations and Research and Design to support Subcouncil activity and to review Subcouncil / Focus Team progress and plans. The TOMC also provides leverage in establishing corporate best practice decisions for all of Lockheed Martin.

EPI brokers, archives, and facilitates processes and archives a repository of corporate published processes. The group serves a central repository for the corporate Lessons Learned Database and Symposium papers. They assist multiple sites is performing tool and software assessments and provide corporate-wide training through training courses in tools, process and methodology and by maintaining website schedules and availability.

Existing tool evaluation and new tool development is also facilitated by maintaining a pool of application engineering support, providing direct support for new tool development and implementation at LMC companies, maintaining tool user group email exploders, and by managing EPI supplier pricing agreements.

Each site has an EPI Leader who is responsible for the implementation of EPI at their site and acts as communications focal point for EPI activities to ensure the site is receiving value from the program. Additionally, Subcouncil and Focus Group members are stakeholders from company sites with an appropriate level of responsibility in the specific process, tool and methodology at their site. Each Working/Process Group has a Team Leader and an EPICenter Facilitator to help them achieve their goals by assembling and coordinating meetings, information, and team deliverables.

The POMTT program started participation in the Commercial Technology Insertion Process group (formerly Working Group) in 2001 to gather corporate expertise and assistance in obsolescence management, take advantage of the tool development and publishing support provided by EPI, and act as a distribution point for the tool evaluations, training, and results of the program.

5.4 Cost of Obsolescence Management

Early in mid-2002, Lockheed Martin Missiles and Fire Control in Orlando performed an analysis to determine the amount of effort applied to, and the costs involved in, obsolescence management on each of their programs. Lockheed Martin found that existing design tools and standards such as VHDL/SLDL for design and redesign, decision support, database management & data integration, reliability assessment, and technology insertion of Commercial Off-The-Shelf (COTS) were not designed to address or intended to help solve the obsolescence problem.

> Note that all values included in this document apply a “standard” labor rate of $100 per hour. Any actual values must be calculated using proprietary burdened and unburdened labor rates.

The review of obsolescence tools and management methods revealed the following:

- GIDEP alert reviews
- TacTech life cycle status check
- Evaluation of new technology families and similar devices
- Interface with DSCC

- Periodic review of OEM Internet pages
- Review of Data P.A.L., IC Master, and other technical publications
- Participation in Industry and Government Committees and Conferences
- Regular status reviews of manufacturers and devices on proactive programs
- Periodic visits to mfg. facilities to discuss obsolescence and observe current capabilities
- Component Obsolescence Management Database (COMAND) and Case History

These were applied in an as-needed, as-recognized, and as-funded manner on a program-by-program basis. For example: approximately one-third of the programs were contracted to actively monitor their parts (only one program surveyed all of their parts). One-third only had funding for a limited solution approach by monitoring only the most sensitive components such as IC's, and the remaining third did not have any funding and could not perform any obsolescence monitoring at all (or relied on their customer to perform any monitoring). A more detailed analysis of those programs that were performing obsolescence management revealed four approaches:

TYPE	***DESCRIPTION***
1	*Active obsolescence management led by Components Engineers*
2	*Obsolescence management through a teaming approach (led by Product Support)*
3	*A reactive type of obsolescence management*
4	*Programs with no Lockheed Martin obsolescence management*

The survey captured the nonrecurring costs associated with each type. The programs used to gather this data include:

PROGRAM	***TYPE***
LANTIRN	1
Patriot	1
Sniper ATP XR	1
TADS/PNVS	2
AGM	3
Hellfire/Longbow Missile	4
Predator	4
Javelin	4

For each program the labor hours required to work an obsolete part problem were collected through three different methods:

- Surveys filled out by the components engineers who worked on those programs
- Interviews with various program personnel
- Financial reports of funds expended on obsolescence activities

Labor hours were captured to estimate the times spent working but, because of insufficient cost data to determine the impact of additional redesign, aftermarket and alternate part costs, industry-estimated cost values from the Defense Microelectronics Activity (DMEA) were used to calculate the total impact costs. These cost factors provide an average cost of resolving DMSMS problems and were applied to calculate the cost avoidance. There were 309 obsolescence issues identified among the five reporting programs, which resulted in a 62 issue per program overall average.

5.4.1 Programs with Active Obsolescence Management led by Components Engineering (CE)

These programs have a lead Components Engineer who proactively identifies obsolescence issues by performing, on a regular basis, such tasks as:

- Ongoing parts reviews
- Assembly or system health assessments
- Manufacturer/distributor phone surveys
- Manufacturer/distributor visits

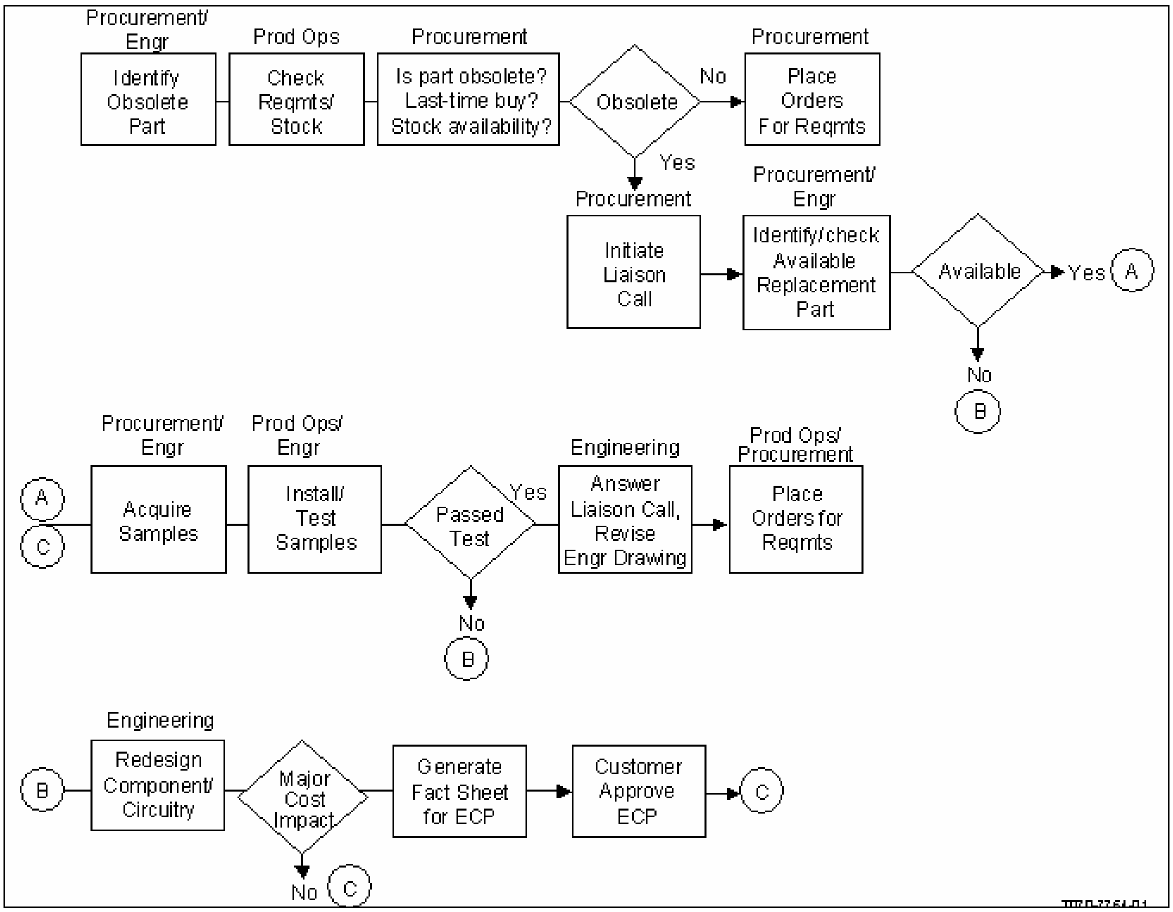
These issues are usually resolved through finding additional external stock, performing a complete Life of Type (LOT) or last time buy, and performing a limited bridge buy.

An overall average of 43 issues per program/per year was worked with mean time of 27.1 hours worked per issue. When the LANTIRN, Patriot, and Sniper ATP XR programs are combined and used as the baseline for cost the total is 3496 hours per year (over a total of 129 issues worked per year). The dollar value associated with those labor hours, along with additional costs of processing NORS and GIDEPS are shown in the summary chart later in this section.

5.4.2 Programs with a Teaming Approach to Obsolescence Management

In this approach, all applicable functions, including Technical Operations, Procurement, Product Support, Quality Assurance, and Production Operations are responsible for obsolescence management. The team manages obsolescence and provides support to all applicable functions using a proactive approach. Actions include: leading, developing, and selecting component/material replacement; identifying and assessing program risk; establishing and monitoring obsolescence criteria for ranking parts; and preparing and presenting recommendations to minimize risk to the program for affected hardware. All Requests for Quote (RFQ's) received for spares and repair parts are evaluated to allow for early detection of any known obsolescence problems that would impact or delay the proposal activity.

In addition to evaluating RFQ's, the team updates the TADS/PNVS parts list against the latest Transition Analysis of Component Technology (TacTech) Report for semiconductors and microcircuits. This provides the team with the latest information on potential obsolete components. Since the team's formation, they have identified alternates and redesigned components to meet their commitments. They have taken full advantage of last time buy and life of buy opportunities to ensure material is available to meet production and spares requirements. See Figure 5.1 (below) to see the obsolescence decision flow model used by the TADS/PNVS obsolescence team.



Area 4 -- Figure 5.1 – Obsolescence Team Resolution Process

Obsolescence issues on these programs are usually resolved by finding additional external stock, performing a complete Life of Type (LOT) or last time buy, alternate parts, and redesigns. An average of 140 issues per year is worked with an average of 35.6 hours per issue spent (TADS/PNVS program is used as the baseline for cost). The dollar value associated with those labor hours, along with additional costs of processing NORS and GIDEPS are shown in the summary chart at the end of this report. Also added in the summary chart is the additional cost associated with alternate parts and redesign.

5.4.3 <u>Programs with Reactive Obsolescence Management</u>

Obsolescence parts issues on these programs are lead by Quality, Engineering, and Procurement, but on a part time basis. They identify obsolescence issues reactively as they occur and primarily resolve them by searching for new vendors. An average of 40 issues per year are worked with an average of 75 hours per issue spent (the AGM program is used as the baseline for cost). The dollar value associated with those labor hours are shown in the summary chart at the end of this report. Also added to the summary chart are the costs associated with processing NORS and GIDEPS, along with redesign, alternate parts, and aftermarket costs.

5.4.4 Programs with No Lockheed Martin Obsolescence Management

For each of the three programs that were surveyed under this approach of obsolescence management the customer handles all obsolescence management and Lockheed Martin has a very limited involvement in their management of obsolescence. The customers provide their own team and LMC Components Engineering only averages about 5 hours per month on obsolescence. The programs included in this group are Hellfire/Longbow Missile, Predator, and Javelin. Cost data from the customer is not available.

Area 5 -- Table 5.1 – LANTIRN Obsolescence Summary

Time period of cost data = 7/00 through 7/02 (25 months)

Average number of labor hours spent per year on managing obsolescence parts = 2294 hours over 25 month period @12 months per year = 1101 hrs per year (.57 m/m average)

Average number of obsolescence issues identified per year = 51

Average number of hours per obsolescence issue = 21.6

Obsolescence Management

Tasks Performed	Average Frequency	Average Hrs Per Task	Sub-total Hours
Ongoing Parts Reviews	every 6 months	5 hrs	10
Assy or system health assessments	every 6 months	18 hrs	36
Manufacturer/distributor phone surveys	every 6 months	2 hrs	4
Manufacturer/distributor visits	as required	40 hrs	80

Solutions Used	Percent of Time Used		Average Hours Used Per Solution	Sub-total Hours
Found additional external stock	92%	46 issues	18 hrs	828
Performed complete Life of Type buy	6%	3 issues	30 hrs	90
Performed limited bridge buy	1%	1 issue	33 hrs	33
Reverse engineered a replacement	1%	1 issue	20 hrs	20
			Total Hours =	1101 (.57 m/m)

Area 6 -- Table 5.2 – PATRIOT Obsolescence Summary

Time period of cost data = 3/99 through 7/02 (41 months)

Average number of labor hours spent per year on managing obsolescence parts = 6953 hrs over 41 month period @ 12 months per year = 2035 hrs per year (1.1 m/m)

Average number of obsolescence issues identified per year = 72

Average number of hours per obsolescence issue = 28.3

Obsolescence Management

Tasks Performed	Average Frequency	Average Hrs Per Task	Sub-total Hours
Assy or system health assessments	35 per year	22 hrs	770
Manufacturer/distributor visits	18 per year	40 hrs	720

Solutions Used	Percent of Time Used	Average Hours Used Per Solution	Sub-total Hours
Found additional internal stock	5% 4 issues	.25 hrs	1
Found additional external stock	95% 68 issues	8 hrs	544
		Total Hours =	2035 (1.1 m/m)

Area 7 -- Table 5.3 – Sniper / ATP Obsolescence Summary

Time period of cost data = 8/01 through 7/02 (12 months)

Average number of labor hours spent per year on managing obsolescence parts = 360

Average number of obsolescence issues identified per year = 6

Average number of hours per obsolescence issue = 60

Obsolescence Management

Tasks Performed	Average Frequency	Average Hrs Per Task	Sub-total Hours
Ongoing parts reviews	weekly	2.5 hrs	130
Manufacturer/distributor phone surveys	weekly	. 58 hrs	30

Solutions Used	Percent of Time Used	Average Hours Used Per Solution	Sub-total Hours
Performed complete Life of Type Buy	90% 5 issues	32 hrs	160
Redesigned Assembly	10% 1 issue	40 hrs	40
		Total Hours =	360 (.19 m/m)

Area 8 -- Table 5.4 – TADS / PNVS Obsolescence Summary

Time period of cost data = 6/01 through 6/02 (12 months)

Average number of labor hours spent per year on managing obsolescence parts = 4980 (Product Support: full time; Engineer: Full time; Components Engineer: half time)

Average number of obsolescence issues identified per year = 140

Average number of hours per obsolescence issue = 35.6

Obsolescence Management

Tasks Performed	Average Frequency	Average Hrs Per Task	Sub-total Hours
Ongoing Parts Reviews	Weekly	10 hrs	520
Assy or system health assessments	Weekly	18 hrs	935
Manufacturer/distributor visits	as needed	40 hrs	480

Solutions Used	Percent of Time Used		Average Hours Used Per Solution	Sub-total Hours
Found additional external stock	30%	42 issues	11 hrs	480
Redesign	5%	7 issues	26 hrs	180
Performed complete Life of Type buy	20%	28 issues	26 hrs	720
Alternate Part	45%	63 issues	26 hrs	1665
			Total Hours =	4980 (2.5 m/m)

Area 9 -- Table 5.5 – AGM-142 Obsolescence Summary

Time period of cost data = 7/01 through 7/02. (12 months)

Average number of labor hours spent per year on managing obsolescence parts = 2988 (Quality, Procurement, Engineering - all part time – 50%)

Average number of obsolescence issues identified per year = 40

Average number of hours per obsolescence issue = 74.7

Obsolescence Management

Tasks Performed	Average Frequency	Average Hrs Per Task	Sub-total Hours
New vendor search	When issue occur	52 hrs	2080

Solutions Used	Percent of Time Used		Average Hours Used Per Solution	Sub-total Hours
Found new vendor (aftermarket)	55%	22 issues	8 hrs	176
Found alternate part	40%	16 issues	40 hrs	640
Redesign	5%	2 issues	46 hrs	92
			Total Hours =	2988 (1.5 m/m)

5.4.5 Costs and Benefits

The following sections describe more fully the impact of obsolescence on program costs including labor, direct and indirect, and other factors related to

5.4.6 Cost Summary

The following tables examine the costs of each of the three different types of obsolescence management at Missiles and Fire Control. Costs associated with redesign, alternate part, and aftermarkets are taken from the DMEA report dated 1999 (with inflation indices applied to escalate the cost to 2002). This was primarily because the cost data at Lockheed Martin could not be isolated.

Table 5.6 – Obsolescence Cost Summary for Programs with Component Engineering Management (3 program average)

	Issues	Labor Hrs	Cost
Avg # of obsolescence issues per year:	43		
Avg # of hours per obsolescence issue:		27.1	
Labor hours on obsolescence management tasks per year:			
Ongoing parts reviews		47	
Assembly or system health assessments		269	
Manufacturer/distributor phone surveys		11	
Manufacturer/ distributor visits		267	
Solutions used:			
Found add'l internal stock	1.3	.25	
Found add'l external stock	38	457	
Performed complete Life of Type (LOT)	2.7	83	
Redesign	.3	13	
Performed Limited Bridge Buy	.3	13	
Reversed Engineered	.3	7	
Found alternate part	0	0	
Found new vendor (Aftermarket)	0	0	
Total number of issues/labor hours spent per program	43	1167	
Total labor cost per year =			**$146,377**
Additional Labor Costs:			
Write NOR'S: (Redesign & Reverse Eng. Issues)			
Low Complexity (@ $186.12/NOR)			
Medium Complexity (@ $812.56/NOR)	.6		$487.54
High Complexity (@ $4,326.78/NOR)			
Process GIDEPS:			
Small (2 hrs each)	55	110	
Large (15 hrs each)	36	540	
Total Additional Labor Costs	91	650	**$81,530**
Total Labor Cost			**$228,395**
Additional Costs:			
Redesign	.3		$35,100
Alternate Part			
Aftermarket			
Total Additional Costs			**$35,100**
Total Cost			**$263,495**

Table 5.7 – Obsolescence Cost Summary for Programs using a Team Approach (1 Program Total)

	Issues	Labor Hrs	Cost
Avg # of obsolescence issues per year:	140		
Avg # of hours per obsolescence issue:		35.6	
Labor hours on obsolescence management tasks per year:			
Ongoing parts reviews		520	
Assembly or system health assessments		935	
Manufacturer/distributor phone surveys		0	
Manufacturer/ distributor visits		480	
Solutions used:			
Found add'l internal stock	0	0	
Found add'l external stock	42	480	
Performed complete Life of Type (LOT)	28	720	
Redesign	7	180	
Performed Limited Bridge Buy	0	0	
Reversed Engineered	0	0	
Found alternate part	63	1665	
Found new vendor (Aftermarket)	0	0	
Total number of issues/labor hours spent per program	140	4980	
Total labor cost per year =			**$624,641**
Additional Labor Costs:			
Write NOR'S: (Redesign & Reverse Eng. Issues)			
Low Complexity (@ $186.12/NOR)			
Medium Complexity (@ $812.56/NOR)	70		$56,879
High Complexity (@ $4,326.78/NOR)			
Process GIDEPS:			
Small (2 hrs each)	47	94	
Large (15 hrs each)	31	465	
Total Additional Labor Costs	78	559	**$70,115**
Total Labor Cost			**$751,635**
Additional Costs:			
Redesign	7		$819,000
Alternate Part	37		$259,000
Aftermarket			
Total Additional Costs			**$1,078,000**
Total Cost			**$1,829,635**

Table 5.8 – Obsolescence Cost Summary for Programs using an As-Needed Approach (1 Program Total)

	Issues	Labor Hrs	Cost
Avg # of obsolescence issues per year:	40		
Avg # of hours per obsolescence issue:		74.7	
Labor hours on obsolescence management tasks per year:			
Ongoing parts reviews		0	
Assembly or system health assessments		0	
Manufacturer/distributor phone surveys		1280	
Manufacturer/ distributor visits		800	
Solutions used:			
Found add'l internal stock	0	0	
Found add'l external stock	0	0	
Performed complete Life of Type (LOT)	0	0	
Redesign	2	92	
Performed Limited Bridge Buy	0	0	
Reversed Engineered	0	0	
Found alternate part	16	640	
Found new vendor (Aftermarket)	22	176	
Total number of issues/labor hours spent per program	40	2988	
Total labor cost per year =			**$374,785**
Additional Labor Costs:			
Write NOR'S: (Redesign & Reverse Eng. Issues)			
Low Complexity (@ $186.12/NOR)			
Medium Complexity (@ $812.56/NOR)	16		$13,001
High Complexity (@ $4,326.78/NOR)	2		$8,654
Process GIDEPS:			
Small (2 hrs each)	0	0	
Large (15 hrs each)	0	0	
Total Additional Labor Costs	18		**$21,665**
Total Labor Cost			**$396,440**
Additional Costs:			
Redesign	7		$819,000
Alternate Part	37		$259,000
Aftermarket			
Total Additional Costs			**$1,078,000**
Total Cost			**$1,829,635**

Table 5.9 – Summary of Solutions by Obsolescence Management Approach

Solutions	Type 1	Type 2	Type 3
Found Add'l Internal Stock	$31	$0	$0
Found Add'l External Stock	$57,322	$60,206	$0
Performed Complete Life Of Type	$10,411	$90,310	$0
Redesign	$36,731	$841,577	$245,540
Performed Limited Bridge Buy	$1,631	$0	$0
Reversed Engineered	$38	$0	$0
Found Alternate Part	$0	$467,841	$192,275
Found New Vendor (Aftermarket)	$0	$0	$1,122,076
Solutions Costs	$106,164	$1,459,934	$1,559,891

When Components Engineering led obsolescence management on a program each issue required an average of 27.1 hours. When a team approach was used each issue required an average of 61.5 hours. When obsolescence was worked in a reactive mode each issue required an average of 74.7 hours. It can be seen that, when CE did not lead the obsolescence effort, the cost increased as the result of using more expensive solutions such as alternate or aftermarket parts.

The average age of the programs in Type 1 is fifteen years or more. The one Type 2 program, TADS/PNVS, started over 20 years ago. Because of its age, the program has had to find many alternate parts to replace the existing parts and have begun to search for new vendors also, which will result in additional costs. Type 3 programs such as AGM started at Lockheed Martin about eight years ago. Since they operate reactively and usually have to search for new vendors as well as alternate parts.

Obsolescence management is primarily a tool for reducing or avoiding downstream costs, rather than generating immediate savings. However, the challenge can be addressed with a proactive, team-oriented approach, based on analyses using tools already available.

Identification of second sources is a costly issue that is not funded by programs until there is a problem. Many development programs barely have enough budget or schedule to complete a design, let alone fund second source development. Programs that are in early design stages do not have Components Engineering on staff. This all gets back to the need for a business plan and detailed business cases that show a large ROI by having the necessary disciplines on board early during design.

5.5 Continual Reviews and Data Collection

Early in the program, after the baselining of existing practices had begun each site began coordinating with program management and obsolescence involved personnel on individual programs to capture and monitor each ones approach to obsolescence management. Tasks were also reviewed to assess any advancement in existing tools and, since these programs were essential to the successful performance of the pilots, close coordination was essential. Reports on past and current efforts were collected and reviewed, along with any plans for future activities. Some of the most significant included:

- 1996 MLRS FCS System Impact Analysis
- 1997 FCS System Impact Analysis
- Electronic Component Obsolescence Assessment of the MLRS M270A1, Dec. 1997.
- System Impact Analysis of the Multiple Launch Rocket System (MLRS) Fire Control System (FCS), April 1998.
- Statement of Work, Aspect Development Corporation, Phase II CSM Implementation, Lockheed Martin Missiles and Fire Control - Dallas, Ver. 1.9, Jan. 2000
- Capital Equipment Acquisition Request, A-1998-C-0049, Component And Supplier Management System, Jan. 1998
- Capital Equipment Acquisition Request, A-1999-S-8008, Component And Supplier Management System Phase III, Jan. 2000
- Configuration Management Plan for Multiple Launch Rocket System, 4-11200/OR-001, 1993
- FY 94 MLRS PRODUCTION CONTRACT DAAH01-94-C-A005 MLRS Parts Obsolescence Statement-of-Work (SOW)
- Preliminary Obsolescence Management Plan For the M270A1, Draft Feb. 1999

As POMTT continued, the team continued to collect and review data and reports, as well as program presentations from internal and EPOI sources including:

- M&FC-Dallas Obsolescence Program Presentations
- AMCOM DMSMS Case Resolution Guide
- DMEA Resolution Cost Factors for Diminishing Manufacturing Sources and Material Shortages (DMSMS)
- Litton’s Electronic DMSMS Roadmap
- i2 Technology’s eDesign Product Description
- Engine Control Service Center Data Collection TIM (Fort Wayne)
- Information Systems' COMMAND Database Review (Orlando)
- Aeronautics Application of Litton TASC Tool for C5 (Marietta)
- VP Technologies Overview and Roadmapping Session (Orlando)
- Lockheed Martin Missiles and Fire Control - Dallas EDA Tool Suite
- Aspect eXplore CSM Training Materials

- Raytheon's LCM Software Requirements Specification
- i2's Life Cycle Management Requirements Specification
- Fort Wayne Service Center reliability data
- CSM Implementation Specifications for i2
- MLRS Obsolescence Program baseline data including work statements, estimates, work flow diagrams, etc.
- F-16 MMC III Development Schedules
- Proven Path Initiative Presentations and Data
- Aging Aircraft SPO Project Call and Organizational Information
- Lockheed Martin Missiles and Fire Control - Dallas EDA Tool Suite
- Aspect eXplore CSM Training Materials
- Raytheon's LCM Software Requirements Specification
- Fort Wayne Service Center reliability data
- Existing reliability tools and models such as those from RAC
- Fort Wayne Service Center reliability data
- Existing reliability tools and models (such as those from RAC)
- Government DMSMS Documents and Teaming Group case data
- Assorted Conference Notes and presentations
- Associated Industry trade journal articles
- Government DMSMS Documents and Teaming Group case data
- DoD Processor Utilization Matrix
- Processor Architecture and Interface Data
- MLRS Fire Control System Support and Demand Data
- GIDEP and Industry Part End Of Life Notices
- Proven Path Initiative Presentations and Data
- Rosetta Language Guides

In Orlando, the LANTIRN Program's COMAND obsolescence database continued to collect data concerning that program's parts, replacement alternatives, and obsolescence resolution. Additionally, industry reports, trade literature, conferences, and workshops continue to be a valuable source of information and obsolescence management data. Data from external sources such as GIDEP Alerts, Diminishing Source Notices, Manufacturer End-Of-Life notices, Government Workshops and Industry Conferences, trade publications, was also collected.

Lockheed Martin Missiles and Fire Control – Dallas's Web Repository (Orbit) continued to add to their library of presentations and other data. The total amount of information available on the site and membership access increased continuously throughout the program.

POMTT also initiated and supported contacts within Lockheed Martin, and with other LMC-external interested parties. For example, at a Lockheed Martin System Integration Lifetime Support IPT meeting in Syracuse, options were presented for a coordinated corporate approach to component obsolescence tools using the i2 LCM content data. This resulted in a request to present the concept at a corporate logistics meeting in Tucson.

POMTT also continued its support of the Lockheed Martin Engineering Process Improvement (EPI) Center Commercial Technology Insertion Working Group (CTI-WG) meetings.

5.6 Metrics Development

Metrics and criteria for selecting and evaluating the tools began being compiled early in the program. Training was obtained to use the Cost As an Independent Variable (CAIV) software program currently in the tool evaluations. Comparisons between tools will only be made where similar functionality exists.

Some of the metrics initially included:

- currency of technology migration data
- interchangeability of microcircuit production technology
- automated rapid design intent extraction
- compliance with industry standards
- simulation and synthesis accuracy/speed
- accuracy/confidence of predictions
- number of alternatives parts considered
- alternatives technologies assessed
- latency of the design data
- completeness of the data
- consistency of the data
- searchability of data
- speed of optimization

Other factors like efficient coupling of the engineering process with other functions (procurement, quality, logistics and manufacturing) can significantly reduce total obsolescence mitigation costs (not just the engineering and redesign process cost). These must be considered as part of the total metrics approach although they are much more difficult to measure.

Advanced development of POMTT's approach to metrics was undertaken using the Process Analysis Toolkit for Affordability (PATA) tool. The team created a basic matrix model of 6 customers, 7 tool configurations, and 24 requirements (which are all grouped into 5 categories). Thresholds, objectives, and weightings were also identified and input for each of the configuration trade (customer to tool) scenarios.

The PATA tool was developed under an Air Force contract by James Gregory Associates and is based on Web-enabled application. It is a Java-based, decision support software program that assists in technology assessment and design analysis in either a desktop or server-based application. Lockheed Martin uses the PATA tool (and its newer replacement – Dynamic Insight) to perform trade studies for new proposals and decision tradeoffs.

The metrics were refined by adding to the initial structure, and adding additional details to the customer, tool configuration, requirements, thresholds, objectives, and weighting criteria. .

In 2001, and at the request of AFRL, POMTT began looking to determine if their metrics approach could be consolidated with Northrop Grumman's. This consolidation would attempt to establish a common review methodology and requirements for the pilots. Northrop's approach however was more specifically cost oriented, and at a higher level since Northrop was only performing a single pilot, and did not use the PATA tool. Although a number of the actual metrics were similar between the two, a hard pilot turn-on would have been required in order to get the final metrics input from program personnel and perform a better comparison to Northrop's metrics. Follow up discussions with Northrop Grumman's were held to help understand their approach but the Lockheed Martin approach appeared to be more detailed and less subjective, primarily because of the PATA tool.

In 2002 additional tailoring continued and the model input into PATA for testing. This testing revealed potential conflicts between tools and customers. For example: an initial assessment of the tool/customer combinations showed that several could fail in some instances. Since there will be no specific pass/fail criteria the model was adjusted to ensure that each evaluation combination would be acceptable so that no one tool could fail. It is also important to ensure that each of the participants do not impact any of decision criteria of the others.

The next step is to perform a preliminary evaluation of each combination using the POMTT team and some outside experts to verify the robustness of the model. A series of meetings were held to review the POMTT metrics in PATA and a portion of these were reworked to ensure the radar charts exhibited reasonable results. Due to the nature and complexity of the trades (multiple customers and multiple requirements) the analysis continued to exercise the model through several planned demo evaluations.

On Monday, June 3rd, POMTT personnel met again with NG personnel in Baltimore to discuss the possible consolidation of obsolescence metrics approaches. A summary of the analysis comparing the two metrics approaches is as follows:

- LM Had 28 metrics

- NGC Had 37 metrics
- Average similarity was 58%
- NGC's lower level breakdown applicable to their product
- LMC's metrics are higher level, applicable to each tool used
- "How Measured" was different for each
- LM Objectives and Thresholds have a quantifiable range
- NGC uses Real Time Continuous Count

It can be seen from the following tables that the differences between the two approaches were due to the types of pilots being performed. Since Northrop Grumman was performing a single pilot on one production program their capture of data, and the location of the data, was much more attainable and allowed much more specific and quantifiable metrics. Lockheed Martin's approach however, was to perform multiple pilots at multiple sites on multiple programs. Capturing and comparing specific metrics such as Northrop used would have been extremely difficult since labor rates, units of measure, and a number of other variables would have had to been standardized. Therefore the CAIV approach was used with a more generic set of metrics that could be applied to each pilot and measured by the appropriate program/users.

NG Metrics

Design Metrics
Number of jumpers
Number of custom parts
Per cent of standard parts
Per cent of custom parts
First time factory yield
Factory yield
Number of redesigns
Sustainment Metrics
Number of DMS parts
Per cent of DMS parts
unplanned

LMC Metrics

Program Performance
Part Coverage
Part Replacement Alternatives
System Data Analysis
Program Schedule
Tool Implementation Risk
Program Total Ownership Cost
Program Usability
Form, Fit Function (Form fit function interchangeable)
Unique Approach (Intellectual Properties)
Training Complexity
Data Output Completeness
Data Input Completeness
Programmatics
Tool/ Developer Stability Ranking
Usability Factor

***Area 10 --* Figure 5.2 – Metrics Comparison**

Although it was decided that the two approaches were not compatible, greater commonization of the metrics and their associated parameters (Units of Measure, Max and Min values, etc.) could be provided. A summary of the identified metrics for the RADSS 2000 and AOA Pilots is provided in Figure 5.3.

Performance

	Requirement	Priority	How Measured	Objective	Threshold Lower	Threshold Upper	Desirability Weight
3	System Data Analysis	Med	# of blank fields	0		6	6.5
4	Obsolescence Recognition (notification time)	High	days	365	30		9
5	Replacement Source Quantity	High	# of sources (part) above current (1)	5	2		8
6	Part Count (System Complexity)	High	decrease # of parts %	50	10		7
7	System Reliability (MTBF) Mean time between failures	High	Hrs	9999	1000		10
8	Prediction Accuracy	Med	Months	6		36	5.5
9	System Changes	Med	# of Changes	0		5	6

Programmatic

	Requirement	Priority	How Measured	Objective	Threshold Lower	Threshold Upper	Desirability Weight
1	Tool/ Developer Stability Ranking	Med	Stability Rank 1-10, 10 = stable	10	5		8
2	Usability Factor	Med	Factor 1 - 10, 1 = lowest	10	4		7

Schedule

	Requirement	Priority	How Measured	Objective	Threshold Lower	Threshold Upper	Desirability Weight
1	Tool Implementation Risk	High	Complexity Factor 1-5, 1 = lowest	1		5	7
2	Schedule Program Impact	High	Level of Impact 1-3, 1 = lowest	1		3	8
3	Production Time Savings	Med	% below current time	25	5		6

Total Operating Cost

	Requirement	Priority	How Measured	Objective	Threshold Lower	Threshold Upper	Desirability Weight
1	Initial Tool Cost	High	$K	0		5000	9
2	Installation Cost	High	$K	0		50	7
3	Initial Training Time	Med	days	1		5	4
4	Recurring Maintenance & Training Cost	Med	$K/Year	0		50	6

Usability							
					Threshold		Desirability
	Requirement	Priority	How Measured	Objective	Lower	Upper	Weight
1	Commercial Technology Insertion (CTI)	Med	%	100	20		5
2	Form, Fit Function (Form fit function interchangeable)	High	%	100	40		10
3	Unique Approach (Intellectual Properties)	Med	uniqueness factor 1 - 5, 1 = mundane	5	2		6
4	Training Complexity	Med	Factor 1 - 10, 1 = lowest	1		5	5.5
5	Data Output Completeness	High	Factor 1 - 10, 1 = minimal	10	4		9.5
6	Data Input Completeness	High	Factor 1 - 10, 1 = minimal	10	5		7

Figure 5.3 - RADSS 2000 Obsolescence Decision Tool Metrics

A detailed analysis of the POMTT and Northrop Grumman approaches revealed an approximate 65% commonality between the two. Northrop however, uses their metrics to measure the difference (decrease or improvement) of all the CPOM selected tools on a single, selected program whereas Lockheed Martin's approach is to apply an appropriate selection of the total metrics to several tool/program pilot combinations. Lockheed's PATA-supported process helps in comparisons where a tool is used on more than one pilot or program. Northrop's makes it difficult to verify a specific tool's benefit over another's. It was agreed that the commonality of individual metrics was the closest the tow could approach.

A summary of the metrics for the i2 LCM and AOA pilots are listed in Figures 5.4 and 5.5.

PROGRAMMATICS		Weight	How Measured	Nominal	Min	Goal
1	Tool/Developer Stability Ranking	60	Stability Rank 1-10, 10 = stable	8	5	10
2	Environ-ment/Administrative Support Ranking	40	Difficulty Rank 1-10, 10 = Low	8	5	10
SCHEDULE		**Weight**	**How Measured**	**Nominal**	**Min**	**Goal**
1	Relative Tool Imple-mentation Risk	40	Risk Factor 1 - 10, 1 = lowest	8	5	10
2	Relative Production Time Savings	60	% Below alternatives	50	20	75
TOTAL OWNER-SHIP COST		**Weight**	**How Measured**	**Nominal**	**Min**	**Goal**
1	Relative Initial Tool Cost	25	% Below alternatives	50	20	75
2	Relative Installation Cost	25	% Below alternatives	50	20	75
3	Relative Initial Training Time	15	% Below alternatives	50	20	75
4	Relative Recurring Maintenance & Training Cost	25	% Below alternatives	50	20	75
5	Relative Server, OS, and Environment Cost	10	% Below alternatives	50	20	75

Figure 5.4 - LCM Metrics

	USABILITY	Weight	How Measured	Nominal	Min	Goal
1	User Interface Usability Factor	40	Factor 1 - 10, 1 = lowest	8	5	10
2	Report Usability Factor	30	Factor 1 - 10, 1 = lowest	8	5	10
3	Administrative Usability Factor	15	Factor 1 - 10, 1 = lowest	8	5	10
4	Training Complexity	15	Factor 1 - 10, 1 = lowest	8	5	10

	PERFORMANCE	Weight	How Measured	Nominal	Min	Goal
1	Relative Part Coverage	15	% Above ave. alternatives	100	50	500
2	Relative Alternative Part Count	5	% Above ave. alternatives	300	100	500
3	Relative Data Accuracy	25	% Above ave. alternatives	300	100	500
4	Relative Response Speed	10	% Above ave. alternatives (Sec. / # of parts analyzed)	100	50	200
5	Relative GIDEP Recognition Delay	15	% Below ave. alternatives (days of delay from GIDEP notice)	50	20	75
6	Relative Supplier Recognition Delay	20	% Below ave. alternatives (days of delay from supplier notice)	50	20	75
7	Relative User Recognition Delay	10	% Below ave. alternatives (days of delay from user notice)	50	20	75

Figure 5.5 - AOA Metrics

The weightings for the AOA pilot metrics are as follows:

- Performance – 20%
- Programmatics – 15%
- Schedule – 15%
- Total Ownership Cost – 25%

In early 2003 the POMTT team in Orlando met with JASSM personnel to review the preliminary metrics established for the i2/JASSm pilot. Jamie Green and Jeanne Meyer-Orench presented the PATA tool and the use of metrics in the project. A preliminary set of measures was presented and discussed. It was established that a limited series of meetings would be required to establish the most applicable measures.

By 2004 the metrics were established for each pilot and were being used to assess the relative merits of each. Quantitative results are included in the final report at the completion of the program. An example of a PATA Benefit/Risk Radar chart is shown below.

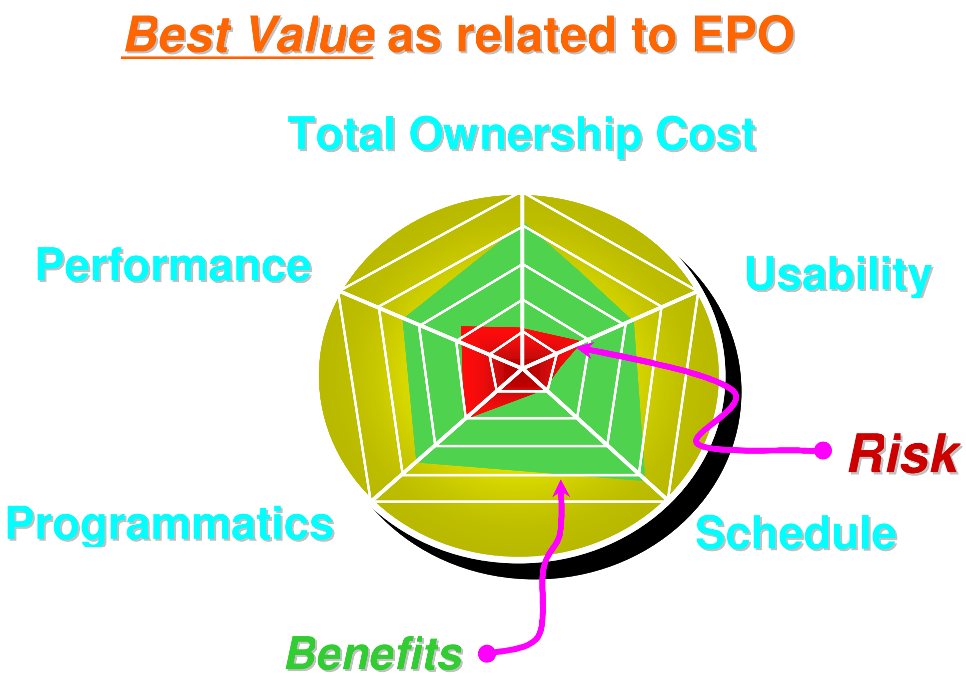


Figure 5.6 – Metrics Benefit/Risk Radar Chart

In this example, the benefits are shown in green and spread across the different areas (Total Ownership Cost, Performance, Usability, Programmatics, and Schedule) and the risks are shown in red. Since the green area is larger and fairly well distributed, it shows that the tools would work well in all areas and that risk is relatively small.

Where the real benefit comes in is shown in the next Figure where radar charts from a number of pilot projects are placed together and compared to see the relative benefits and risks as each is applied.

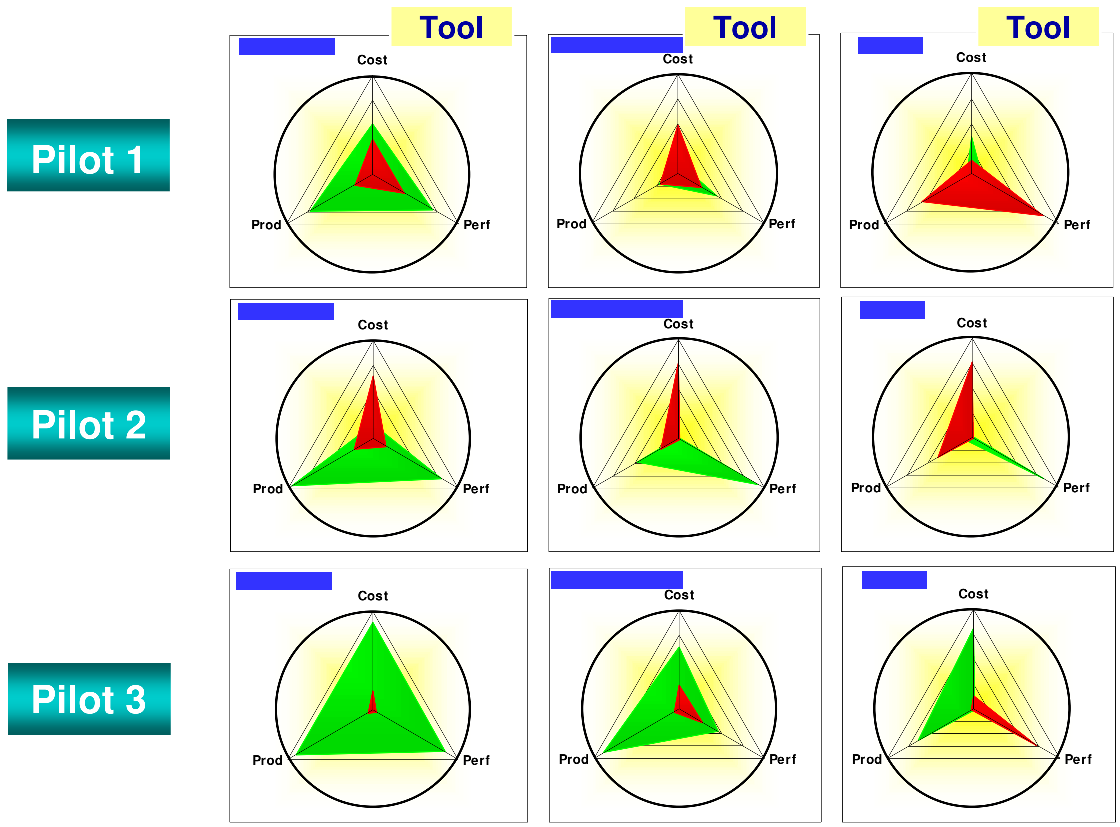


Figure 5.7 – Radar Chart Comparison Matrix

If there were enough time and funding to perform multiple pilots this would be an extremely valuable aid in determining the type of program that each tool supported best. Unfortunately, there was not enough time and funding to perform this many pilots and provide this level of detail.

Section 6

EPOI Tools and Methodologies Analysis

This section identifies those tools and technologies involved in ACME/PO that were not selected for a specific pilot. Details concerning their non-applicability for use at each site are provided as well as POMTT's understanding of the tool's potential for the future.

6.1 Background Data and Research

This work consisted of gathering data about each of the tools, its competitors (if any), and research concerning its purpose, application, use, and support structure. Developer data and their documentation were captured (as available) and were maintained at each site.

In some cases data was not provided by the developer nor was communication available or encouraged. For example: all information dealing with the Motorola reliability study for commercial IC's was gathered from public, AFRL, and EPOI Workshop presentation materials. Motorola did not communicate or respond to requests for information from POMTT due to company concerns. Therefore, there were no pilots using their capabilities/tools.

However, many of the tool developers were supportive, although not all at the same time. Each of the tools was being developed under separate contracts and schedules. Therefore, the POMTT team began participation and support of the tool development after, during, and even before initial development had begun. For example: At the start of the POMTT program (September, 1999) Aspect Development was originally under contract to update their parts obsolescence prediction capability available through their TacTech tool. However, after about six months (March, 2000) they were acquired by i2 Technologies and development on the new capability was delayed another 6 months as the new company integrated Aspect's capabilities and products. The project was therefore delayed approximately one year while all of this transpired. Around September, 2000 i2 published a User Requirements document that was prepared by Raytheon and distributed it around to their user group (of which Lockheed Martin – Dallas was a member) for their review and input and the project continued on track from then on. One issue to consider was that, during this time and immediately after it, there was a considerable turnover in personnel due to the company takeover and a downturn in the economy.

Articles, trade journals, and other reference information were searched to identify the state of the industry and market potential for each tool. A number of sources were used including:

Aviation Week & Space Technology

COTS Journal

EE Times

Electronic Design News (EDN)
Aerospace Engineering
Electronic Design

6.2 Tools not Selected for Pilots

The following tools/technologies were not selected or used in any pilots:

- ***Synopsys' Behavioral Product Reengineering (BPR)***
- ***Boeing Reliability***
- ***Motorola Reliability***
- ***Northrop/Averstar POET***

Each one had specific reasons for not being selected and these are detailed in the following sections.

6.2.1 Synopsys Design Environment (SDE) & Behavioral Product Reengineering (BPR) for System On a Chip (SOC) Design

The primary purpose of the Synopsys Design Environment (SDE) & Behavioral Product Reengineering (BPR) project at TRW was to facilitate System On a Chip (SOC) Design through the development of commercial tools and methodologies. The benefit of this was expected to be a reduction in parts obsolescence on new weapon systems.

The TRW-led team consisted of Synopsys, the University of Cincinnati and EDAptive Computing, Inc. They participated in bringing together two products: one from Synopsys that supports development of a Simulatable Specification (SimSpec) to speed up the product design and reengineering process and the other from EDAptive which addressed the automatic generation of test vectors. The test vector generation was evaluated in a LMC-Dallas pilot and is addressed in Section 7. The BPR approach was not piloted.

SDE is a UNIX software system of programs and Synopsys scripts which IC designers use for HDL-based design. It defines a consistent directory structure and is user-configurable methodology for synthesis, simulation, verification and test of a design from HDL to a final netlist.

The BPR technology was based on Synopsys' VHDL behavioral synthesis CAD environment and accepts a SimSpec as the basis for synthesis. Use of this approach allows electrical engineering designers to develop electrical (system and ASIC) designs that will facilitate reengineering if they go out of production on the future.

TRW and Synopsys' proposed approach was to apply SimSpec at every design level including subsystems, boxes, boards, components and design reuse element and design at a higher level by moving from RTL to Behavioral level design. This would potentially reduce the reengineering effort for each item and provide a level of technology independence. The approach is illustrated in the graphic Figure 6.1 below.

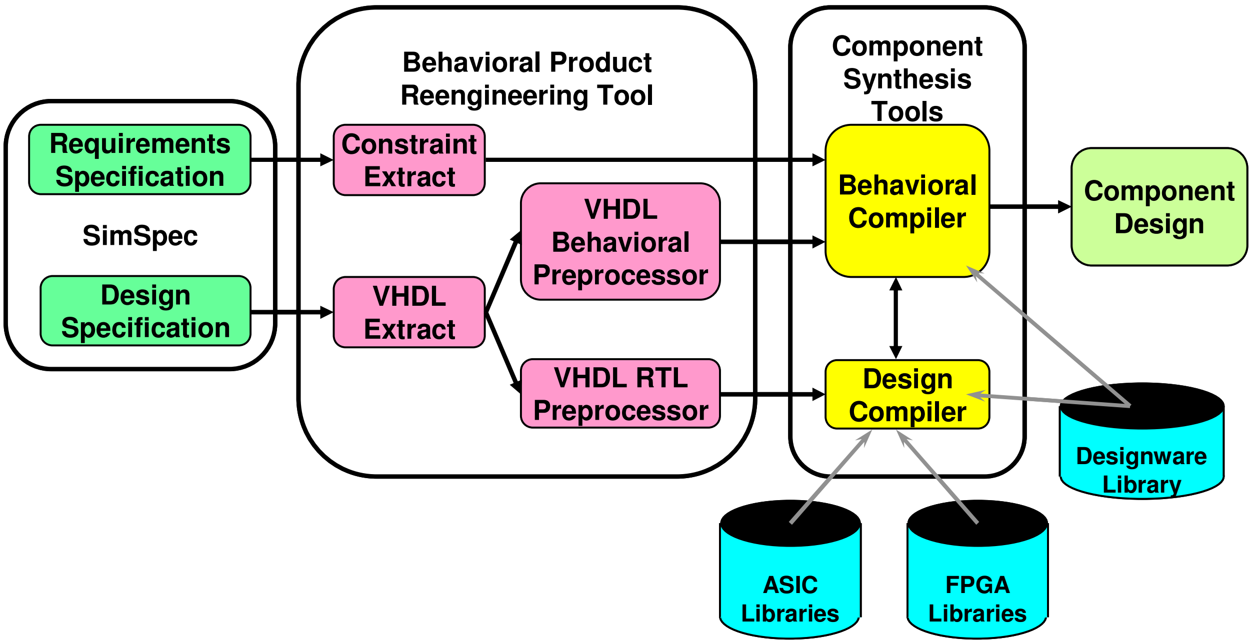


Figure 6.1 - Synopsys Behavioral Design Approach

Through this method the implementation-independent information is captured in a Simulatable Specification written in the VSPEC format. The Simulatable Specification is parsed and the necessary information is compiled into a discrete files. SDE supports a number of compilers, verifiers, simulators and analyzers.

This toolset was not selected due to several factors, and at more than one site. For example: the complexity of designing using the Synopsys tool suite would have been very difficult to LMC - Dallas since they have already standardized on the Cadence tool suite for their electronic design. They would have had to obtain special licensing for the Synopsys software development suite and undergone training on the tool set in order to begin the evaluation. Lockheed Martin – Orlando, on the other hand, already uses the Synopsys tools but faced two problems: The first being that the component level designers did not see an advantage of designing at a higher level, and the second that system level designers had little interest in using a tool that supported development of individual IC components. Clearly, in this case there was a culture issue stemming from the existing paradigm on the methods used to design new systems. It should be noted also that the Systems engineers were already involved in an effort that included reviewing system level design approaches and tools and, although they participated in a review of the tool, it did not generate any greater interest in this particular approach.

6.2.2 Boeing's COTS Reliability Validation and ASIC Solution for Aerospace Systems

Boeing's approach to the obsolescence problem took two paths. The first was to address retargeting of mixed signal designs to new technologies through the use of the

NeoCell tool and cell library, and also addressed the limited availability of ASIC foundries to fabricate these in small part quantities. A pilot was performed using this approach at Lockheed Martin – Orlando and is addressed in Section 7.

The second path addressed reliability concerns of commercial components such as the lack of correlation between field returns and analysis tools and little to no validation for high density packaging such as commercial BGA packages. There was however, little data available for emerging technologies such as CSP, Micro-BGAs and Flip Chip. This was of particular interest to the POMTT program and, although no pilot was performed with Boeing in this area, BAE Systems Controls performed a similar pilot with Georgia Tech to validate BGA solder ball models. This pilot is defined in Section 7.

The Boeing reliability project's goal was to provide an integrated reliability prediction tool for use in parts selection and qualification. The benefit being to increase use of commercially manufactured electronics, especially as potential replacements for military parts. Tasks would be performed to enhance and validate their current software tools to more accurately predict the reliability of specific commercial parts based on their manufacturing technology and processes, and then correlate their reliability data to the parts operational environment. The five tasks they defined were:

Task 1: Failure Data Collection and Analysis
Task 2: Component Level Reliability Studies
Task 3: Assembly Level Reliability Modeling and Life Prediction
Task 4: Model Validation with Field Data and Test Measurements
Task 5: Integrated Reliability Tool Development

These were intended to refine and validate the process flow illustrated in Figure 6.2.

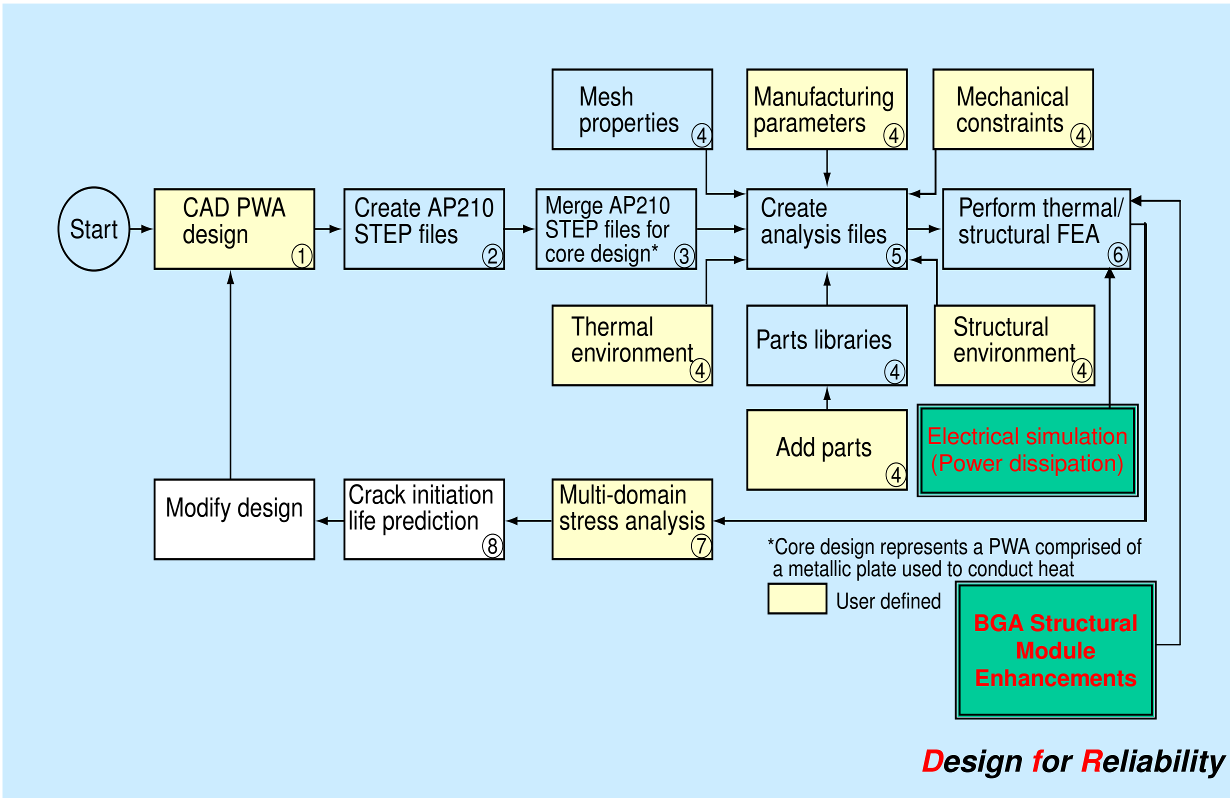


Figure 6.2 – Boeing's Design for Reliability Approach

In Orlando, discussions with Reliability Engineering revealed interest in this approach, but again a paradigm of existing practices tempered their response. Current practice is to use MIL-HDBK-217 (Reliability Prediction of Electronic Equipment) and its historical reliability estimates to calculate component reliabilities, and these are summed up to help provide system reliability estimates. However, these values are based on older data generated by MIL-Spec governed parts. Newer commercial parts typically have much higher reliabilities, but are not measured in extreme military environments. Additionally, newer reliability estimating tools (such as from RAC) that are being used at Lockheed Martin are being supplied with commercial component reliability estimates and the tools have the ability to accept external predictions as well. Although the group recognized that these had not been cross-system validated, they argued that they were available and subsequently validated for each individual system.

Additionally, there is an expectation that each reliability model would be applicable only to parts used and validated in a particular design, and that there are hundreds of designs not yet modeled that the parts would have to be validated for as well. Therefore, engineers were willing to use the physics of failure based approach but felt that it was too limited in scope to help them do their job.

6.2.3 Motorola Reliability

The goal of Motorola's reliability project appeared to be very similar to Boeing's and would help develop a simulation and modeling approach to accurately predict the reliability of their commercial telecom products. They would do this by identifying some of their key failure mechanisms and their root causes and enhancing their existing physics-of-failure based life prediction models. They would also correlate the models through field return data, failure analysis results, and optomechanics-based experimental techniques. The final goal was to develop neural network based software tool that integrates all of the validated and enhanced models.

Some of the issues they were concerned with included cracked/broken wirebonds, cracked/stressed die, contact voiding, and delamination of the die substrate. These are illustrated in Figures 6.3 and 6.4.

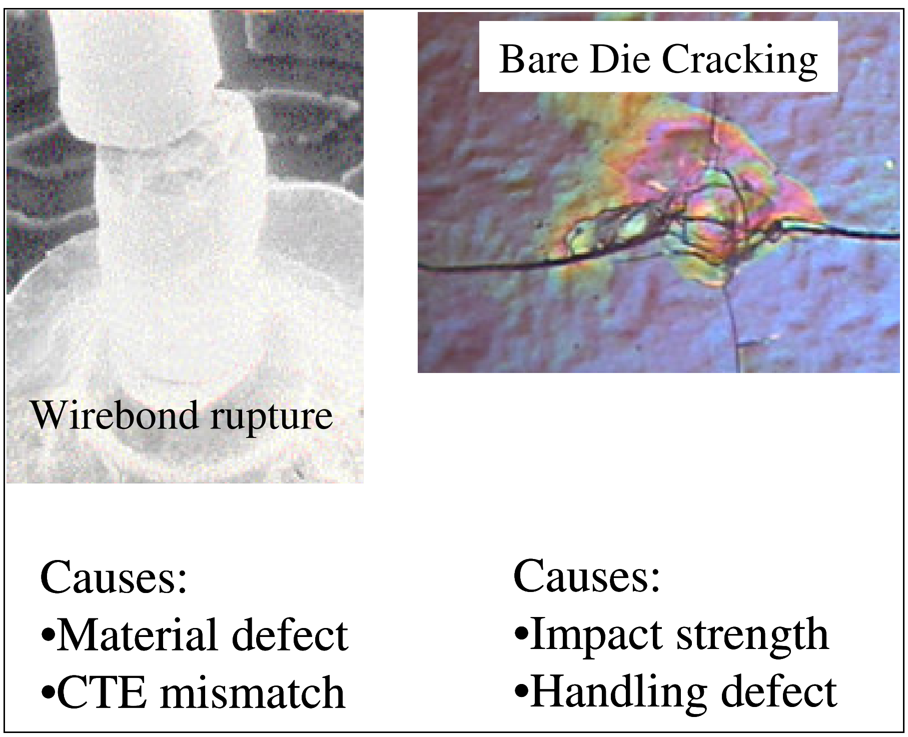


Figure 6.3 – Motorola Design for Reliability Issues

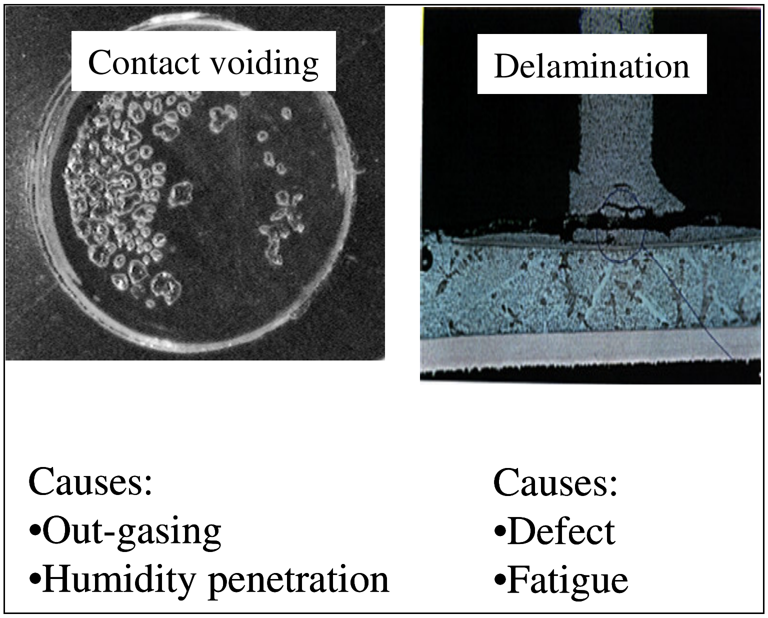


Figure 6.3 (continued) – Motorola Design for Reliability Issues

The Figure below shows some of the areas that are of concern to military systems designers since defense and aerospace applications are typically much more severe than most commercial uses. Moisture intrusion and absorption by molding compounds, cracked and degraded wire bonds, delamination, and outgassing at low atmospheres are problems encountered by designers when applying commercial components in extreme environments.

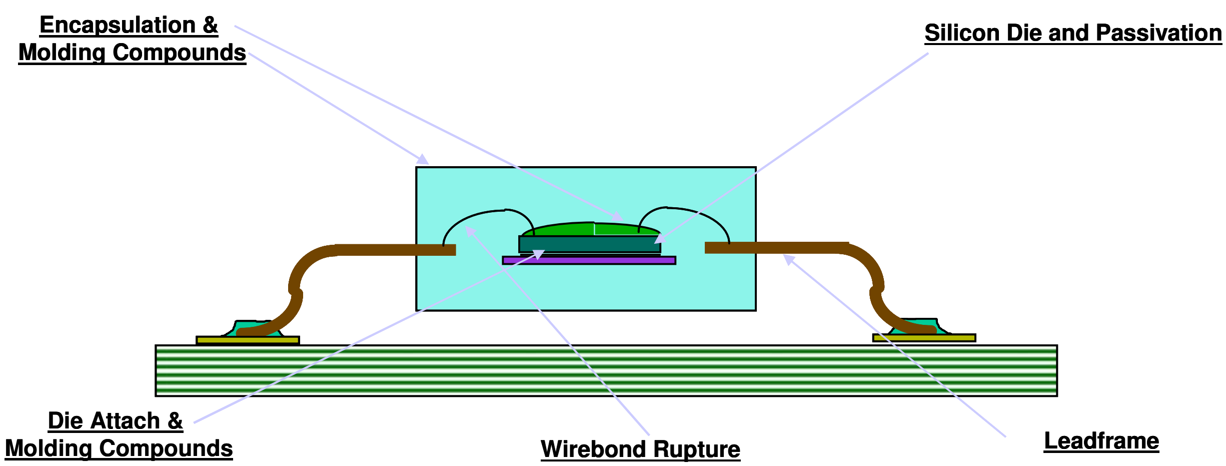


Figure 6.4 – IC Cross-Section

Although the POMTT team was very interested in this project's results, and particularly in the emphasis on commercial components, data from Motorola's program was very limited. Motorola had previously stated that they were willing to share information concerning:

- Failure mechanisms/modes analysis results based on field return data, failure analysis, and statistical analysis for commercial electronic applications
- Benchmark analysis results of existing "physics-of-failure" reliability models and life prediction methodologies both in component and assembly levels
- To-be-developed enhanced "physics-of-failure" reliability models, including component model library, material databases, and multi-level solution procedure (global-local approach)
- Advanced experimental measurement procedures and statistical/regression analysis techniques for reliability models validation
- Advanced software technology (tool/database integration, trained neural network or "reliability training vehicle," etc.) for accurate reliability prediction of commercial electronics/parts

Unfortunately, their data and results were extremely limited to those presentations made at the EPOI Workshops. Additionally, project management changes at Motorola made communication very difficult, even when specifically requested by POMTT. Therefore, team consensus was to focus on Georgia Tech's approach since they were much more willing to share data and interested in collaboration.

6.2.4 Northrop/Titan Systems POET

Northrop Grumman's project with Titan Systems (formerly Averstar Inc.) was designed to integrate electrical design and analysis tools such as Mentor, Matlab, Metaphase, etc. through a Web-based software front-end. This front-end program would also provide workflow management and be designed using the Rosetta System Level Description Language. The expected benefits were that this approach would provide more data consistency and support regression testing.

Lockheed Martin – Orlando already had a mechanical integrated design approach that was very similar to this. They looked at the investment required and did not see enough funding to work a project of this size. They also reviewed the issues facing developers such as the lack of an existing infrastructure, the lack of available translators, and relatively little existing documentation and decided it would be better to wait until Northrop's development was further along. This was supported by the fact that many of Northrop Grumman's tools were the same as those at Lockheed Martin. Additionally, the work procedures used at Northrop were also very similar to Lockheed's since both companies originated in the same geographic location and many employees worked for both companies and provided cross-pollination of methods and processes.

Therefore, Lockheed Martin decided to wait until the infrastructure was established including the interfaces with the different tools. The company will continue to review their progress and look for future funding potential.

Section 7

Technology Pilots

There were two types of pilots contracted as part of the POMTT evaluations: Technology (or Soft) pilots and Production (or Hard) pilots. Five Technology pilots were actually performed and are discussed in this section. The 5 other Production Pilots performed are discussed in Section 8. These Technology pilots used the ACME/PO tools in evaluations but no changes were required to be made to the participating system, although they may have used the program's participation, manpower, or data.

The five technology pilots performed during the project were:

- VP Technologies' (VP) Redesign of Lockheed Martin Missile and Fire Control's (LMM&FC) Longbow Missile Video Logic Driver Hybrid ASIC
- Boeing Small Scale Electronics Development's (SSED) retargeting of LMM&FC's Hellfire Missile Automatic Gain Control (AGC) Pre-Amp ASIC
- The University of Maryland's Mitigation Obsolescence Cost Analysis (MOCA) obsolescence planning tool for LMM&FC's Target Acquisition and Designation Sight Modernization (MTADS) Program
- Integration of The University of Maryland's MOCA and Frontier Technology's (FTI) Integrated Cost Analysis (ICE) Obsolescence Cost Analysis Tools for LM Aeronautics' F-16 Program
- Application of NGIT's RADSS 2000 Decision tool at LMM&FC's PCB Manufacturing Technology

The details of these pilots are detailed in the following sections.

7.1 VP / Longbow Pilot

The purpose of the Longbow FPGA conversion soft pilot was to evaluate VP Technologies methodologies and potential reduced cost and time to market. The pilot should also produced a benefit by reduce the risk of using VP Technologies and increasing program confidence in the small company.

VP Technologies developed a methodology for converting legacy designs that they called Parametric Hardware Models (PHM). This methodology automates the legacy design conversion that is currently done manually and potentially reduces the time it takes to recapture a design.

Along with VP Technologies' methodology, Lockheed Martin evaluated VP's claim that they can recapture a legacy design and reduce the cost and time by one third. Lockheed Martin has captured cost data on several commercial companies along with current in-house data. This data was then compared to the data generated from the pilot. Along with the cost data Lockheed captured the time required to take the Longbow Hybrid to market.

Since VP Technologies is a small start up company there was an inherent risk in applying the concepts developed at the University of Georgia Tech by Dr. Madisetti. These concepts had not been implemented into real world processes as, at the start of the project, VP had not produced any physical hardware based on their models or recaptured designs. It was expected though that, as VP's experience increases, this risk would be expected to diminish.

7.1.1 Longbow Video Logic Driver FPGA

Longbow's Video Logic Driver hybrid contains an obsolete Altera FPGA die. This die is no longer commercially available and the program had a limited amount of die remaining. To continue production of the missile the Longbow program decided to upgrade the FPGA to an ASIC replacement which must have the same:

1. Form: The design must provide a die instead of a packaged chip.
2. Fit: The die can be no larger than the original FPGA die.
3. Function: The chip must function identically to the original chip.

Once the ASIC is produced the program will mount the die into the hybrid, bond the connections, and have the entire package tested.

7.1.2 VP Technologies

VP Technologies, Inc. has developed proprietary and advanced in two key business areas: legacy VLSI processor emulations and embedded system retargeting. VP licenses emulations of obsolete or legacy VLSI processors, with complexity ranging from several thousand to several million gates, to help mitigate the effect of parts shortages or obsolescence. They also retarget still-existing electronics systems to newer platforms, without the need for legacy software redesign, through the use of advanced VHDL-based virtual prototyping technologies.

VP Technologies' Intellectual Property (IP) encompasses a large number of microcircuit and electronics design problems including: legacy design extraction, legacy design analysis, compiler efficiency and code generation, VLSI processor and board emulations, ASIC/FPGA synthesis, SmartSupplyChain™ technologies, system-level virtual prototyping & test, and rapid technology insertion. VP has dedicated internal research & development efforts to understand these problems and offer comprehensive, timely, and cost-effective solutions to their customers.

7.1.3 Lockheed Martin

Lockheed Martin's current practice for converting the Longbow FPGA first requires capture of the legacy data. Once gathered, an ASIC designer would review (in this case) the legacy model and any supporting documentation. After this review the designer then suggests to the program the best path forward. One potential solution was to have a designer modify the ABEL code and leave the design in ABEL a previously used modeling language. Another solution considered was to recreate the design in Verilog (the current preferred modeling language). This process involves manually converting the code to the new design. A final solution was to have the design sent to an outside vendor for replication using a newer technology. This last option is typically done on a limited basis. In the case of the Longbow FPGA the ASIC department was unable to apply the necessary resources and manpower, and due to the time constraints the program elected to outsource the design. As part of the evaluation the POMTT team also gathered the data as if Lockheed Martin was going to produce the chip in-house.

7.1.4 Pilot Objectives

The goals of the conversion pilot were the following:

- First, record the methodology in the design recovery and retargeting of the Video Logic Driver hybrid circuit.
- Second, outline VP Technologies' proprietary methodology [Parametric Hardware Models (PHM)], for translating the legacy implementation of the part to a technology independent, Very High-Speed Integrated Circuit (VHSIC) Hardware Description Language (VHDL) model.
- Third, demonstrate the successful translation of the legacy design to VHDL code.

This would be followed by successful retargeting to a new ASIC.

The pilot's Statement Of Work (SOW) included requirements to convert the original hybrid FPGA to a single ASIC using the HDL code, schematics, test benches and compiler report information provided by Lockheed Martin. VP Technologies would only design a functional equivalent of the present FPGA. Due to limited funding, no part fabrication was requested and no packaged devices were produced.

7.1.5 Original Device Specifications:

The ASIC was required to meet the functional and performance requirements of the original FPGA die as detailed below.

1) Altera EPM7096A
    a. 1800 gate FPGA
2) Pad usage:
    a. 64 signal pads
    b. 8 power pads, 8 ground pads
    c. Power and ground pads must be able to support double wire bonds
    d. All inputs and outputs operate at TTL logic levels
    e. Maximum load of 3ma on all outputs
3) Power supply voltage: +5V, 10% tolerance
4) Maximum clock rate: 7.5MHz

5) Minimum strobe pulse width: half a clock cycle
6) Maximum propagation delay, strobe to output: 50ns
7) Operating junction temperature range: -43C to 125C
8) Originally designed using Max Plus II CAE tools
    a. Tar database was provided
    b. Content of tar data base listed in Appendix A
9) Basic functions performed by the FPGA:
    a. Convert serial bit stream (8 or 11 bits) using clock to parallel words for use as a control word and as data and address for EEPROM
    b. Generate control signals, address and data for an EEPROM (AT28C16)
    c. Generate discrete switch logic control signals based on control word and truth table

VP Technologies was required to provide the following deliverables:

1) A functional VHDL model of the ASIC
2) Simulation results that match the functional operation of the original simulations and meet timing requirements.
3) A summary report of total man-hours and number of people used.
4) Total costs to complete the ASIC.
5) A detailed Final Technical Report defining the complete technical effort required for development, tools/software/methodologies used, costs, benefits, and performance of the new design in comparison to the original specification requirements.

7.1.6 Legacy Design

An analysis of the original legacy design was required and performed by VP. The original design was done in Advanced Boolean Expression Language (ABEL) which is a hardware description language first released in 1983. ABEL was developed by Data I/O Corporation and its strength lays in its similarity to the hardware it describes. Although more recent HDL's (like Verilog and VHDL) provide support for more complex designs, ABEL lends itself to hardware design much more directly and it was ABEL's unique hardware likeness that was required in this project.

The original functional design was divided into a Truth Table and the supporting logic. The table was implemented in the legacy design through a series of ABEL specific table structures. These six tables represented about 66% of the total design. One third of the design consisted of 30 flip-flops, a 4-bit adder, 3 tri-state buses and other concurrent logic. The adder was used in conjunction with the other logic and a number of DFF's to determine whether the hybrid was in its operating mode, or in a programming mode.

The legacy design was found to take up 75% of the gates in the original MAX7096A Altera FPGA. Figure 1 shows the functional design of the chip including the Truth Table.

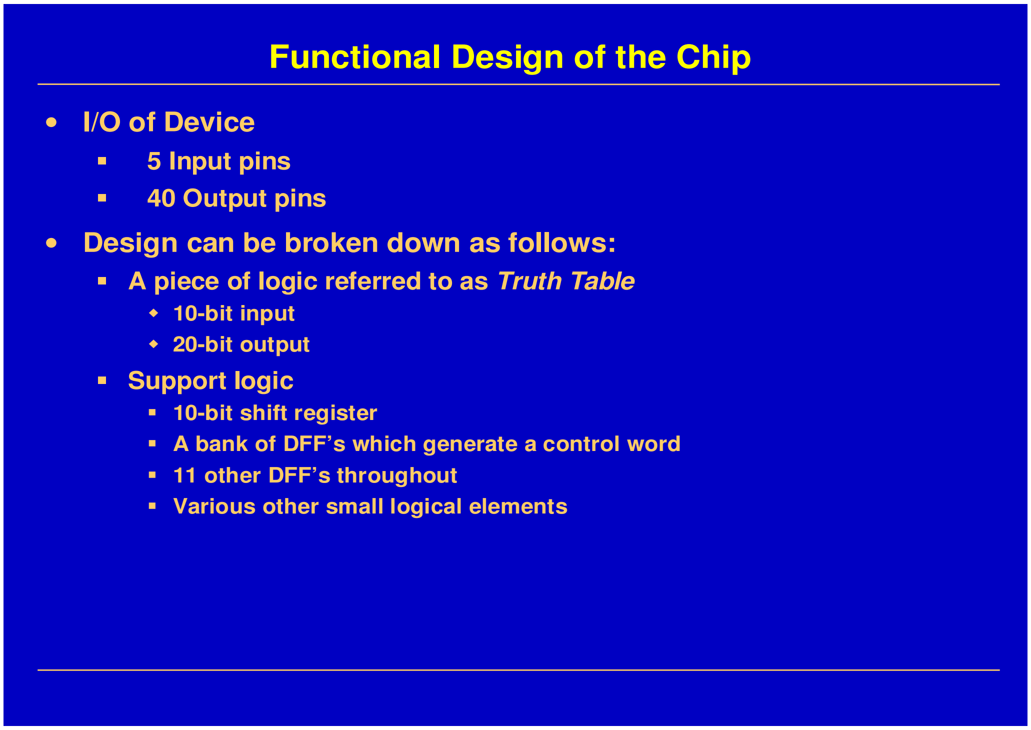


FIGURE 7.1 - Functionality of the Legacy Design

The most significant piece of the Hybrid is a block of concurrent logic named Truth Table. Shown in Figure 7.2 (below) the Truth Table was implemented in ABEL, in the legacy design, using a series of TABLE statements and D-flip flops. The logic inputs an 8-bit control vector along with two other control bits. It generates a 20-bit output that runs through a bank of flip-flops and three other 1-bit outputs that control other logic in the Hybrid. Of the 1600 gates in the legacy design Truth Table represents about 1000 gates, or almost two thirds of the entire design.

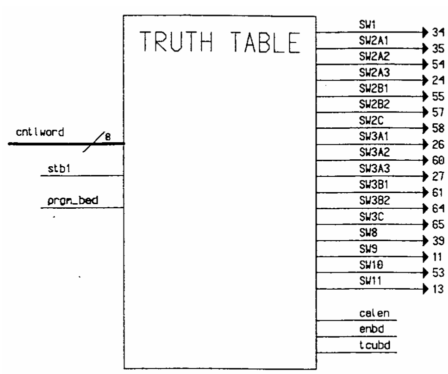


FIGURE 7.2 - Truth Table Element

7.1.6.1 Physical Design

The EPM7000 family of high-density Programmable Logic Devices (PLD) is based on Altera's second-generation MAX architecture (see Figure 7.3). Fabricated with CMOS technology, the EEPROM-based family provides 600 – 5000 usable gates, ISP, pin-to-pin delays as fast as 5 ns, and counter speeds of up to 175.4 MHz.

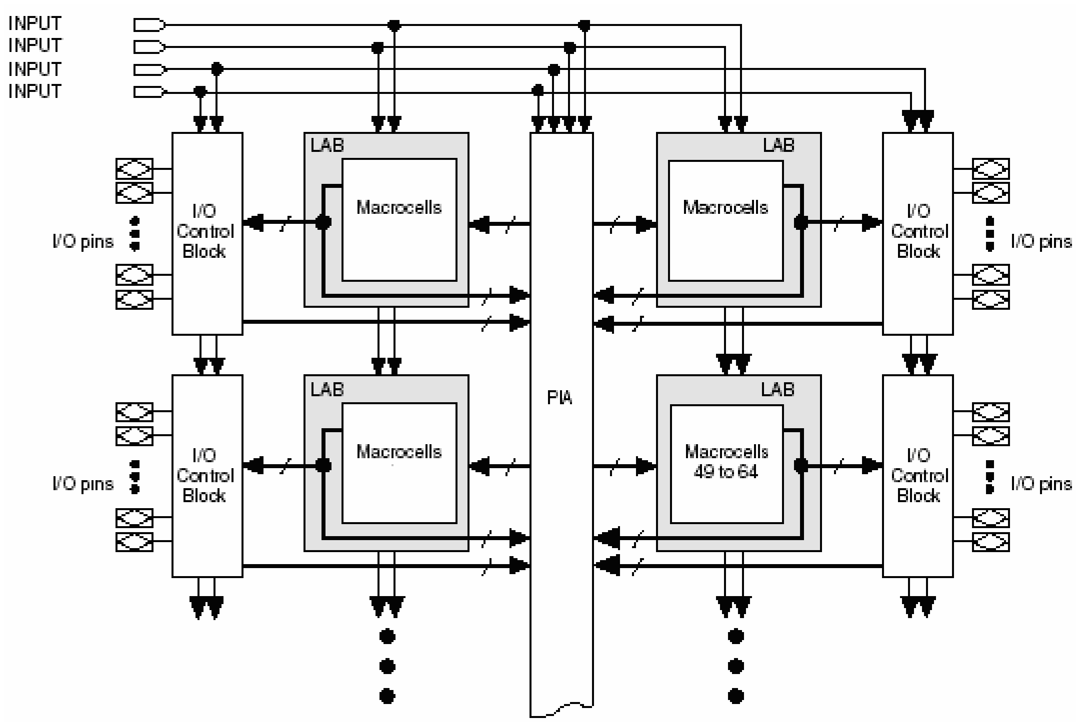


FIGURE 7.3 - Block Diagram

The 1800 gate FPGA chip itself uses:

- 64 signal pads
- 8 power pads, 8 ground pads
- Power and ground pads able to support double wire bonds
- All inputs and outputs operate at TTL logic levels
- Maximum load of 3ma on all outputs.
- Power supply voltage of +5V, 10% tolerance
- A maximum clock rate of 7.5MHz
- A minimum strobe pulse width of half a clock cycle
- A maximum propagation delay (strobe to output) of 50ns
- An operating junction temperature range: -43°C to 125°C

7.1.7 Conversion Process

In order to expedite the translation from ABEL to VHDL, the following methodology was employed by VP: the legacy ABEL design was reduced into a series of Parametric Hardware Models from which the entire project could then be represented. The models were then mapped to VHDL. After that, the bulk of the translation became a highly automated mapping project. This is illustrated as:

Process Flow

ABEL → Parametric Hardware Model (PHM) → VHDL

The translation from ABEL to VHDL can be characterized as a combination of direct, indirect, and interpreted conversions.

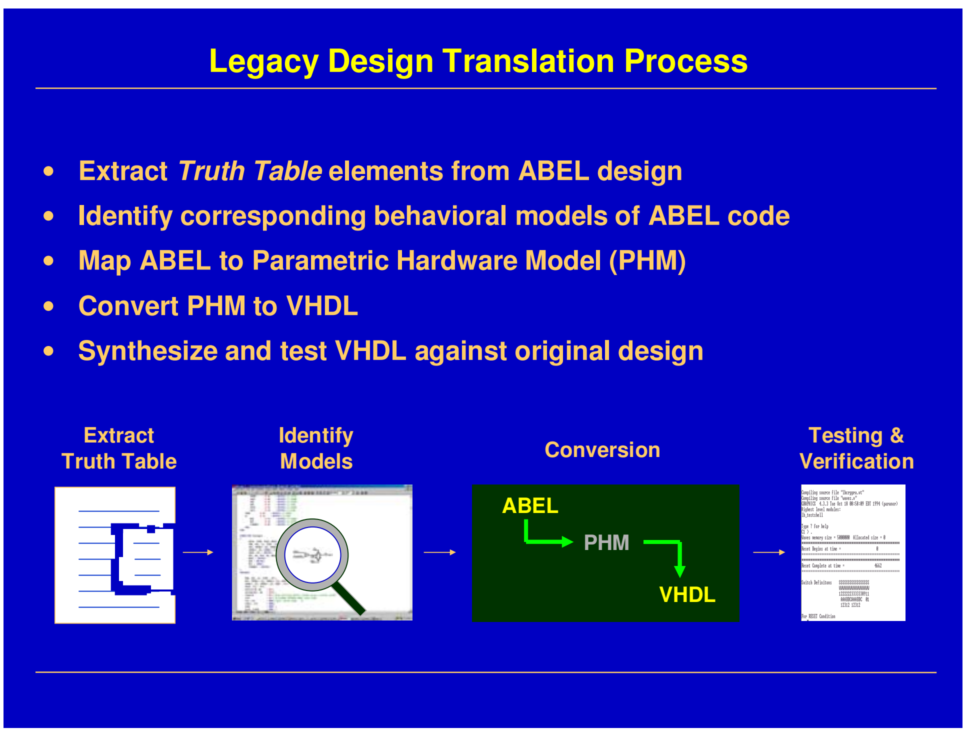


FIGURE 7.4 - Legacy Design Recovery & Translation Methodology

Direct Conversion was the most desired situation in the conversion process. As the name implies, code that went through a direct conversion was mapped from one language to another with little to no changes. The names of signals converted directly as well as a few of the simple signal assignments.

Indirect Conversion was however, a much more prevalent situation in the conversion process. A functional block of ABEL that could be easily translated to VHDL through the use of a model characterized itself as an indirect conversion. The TABLE block of ABEL code shown in Figure 7.5 is one such example.

```
TABLE
input1, input2, ... , inputN => output1, output2, ... , outputM;

in1_value1, in1_value2, ... , in1_valueN => out1_value1, out1_value2,
... , out1_valueM;
in2_value1, in2_value2, ... , in2_valueN => out2_value1, out2_value2,
... , out2_valueM;
  .          .                 .              .            .
.
  .          .                 .              .            .
.
inJ_value1, inJ_value2, ... , inJ_valueN => outJ_value1, outJ_value2,
... , outJ_valueM;
END TABLE;
```

FIGURE 7.5 - ABEL Code Example (Legacy)

The TABLE construct has a potential N inputs and M outputs. For each of the J input cases there are J output cases. Because VHDL has no TABLE construct of its own, a workaround was devised.

```
IF(    input1 = in1_value1 AND input2 = in1_value2 AND ... AND inputN =
in1_valueN) THEN
      output1 <= out1_value1;
      output2 <= out1_value2;
              .              .
              .              .
      outputM <= out1_valueM;
ELSIF( input1 = in2_value1 AND input2 = in2_value2 AND ... AND inputN =
in2_valueN) THEN
      output1 <= out2_value1;
      output2 <= out2_value2;
              .              .
              .              .
      outputM <= out2_valueM;
ELSIF( ... ) THEN
                        .
                        .
ELSIF( input1 = inJ_value1 AND input2 = inJ_value2 AND ... AND inputN =
inJ_valueN) THEN
      output1 <= outJ_value1;
      output2 <= outJ_value2;
              .              .
              .              .
      outputM <= outJ_valueM;
END IF;
```

FIGURE 7.6 – VHDL Code Example

The TABLE construct was recognized to be a compacted Else-If statement. Once identified as an Else-If statement, the ABEL quickly lent itself to a translation map, as shown in Figure 8. Other, more direct models included the tri-state buffer, the D-Flip Flop (DFF), and the D-Flip Flop with enable. The identified models were reused throughout the translation process to allow for quick legacy-design to VHDL conversion.

Interpreted Conversion was the worst-case form (in terms of design difficulty) of translation in which to be engaged. When no obvious model could be identified, legacy functionality had to be extracted and replicated in VHDL in a non-obvious way. One such situation of interpreted conversion involved a few of the TABLE constructs. While each TABLE block could be converted to VHDL by itself, some of the individual tables worked together in such a way that using the else-if model became destructive. Specifically, a few of the tables, when converted to Else-If statements, provided different functionality depending on the order of the said statements.

The first step in the conversion process was to isolate the Truth Table components from the rest of the design. It was comprised of two global inputs (to control the DFF’s), 17 DFF’s, a 17-bit internal vector, and six TABLE blocks. The TABLEs took a variety of inputs ranging from the top seven bits of the control vector to all 10 input pins. The 17-bit internal vector was driven by the TABLE logic, which in turn ran into the bank of

DFF's. For the purposes of testing, the signals into and out of the Truth Table that were not already externalized were routed outside the design. A waveform was generated based on the extracted design and is shown in Figure 7.7.

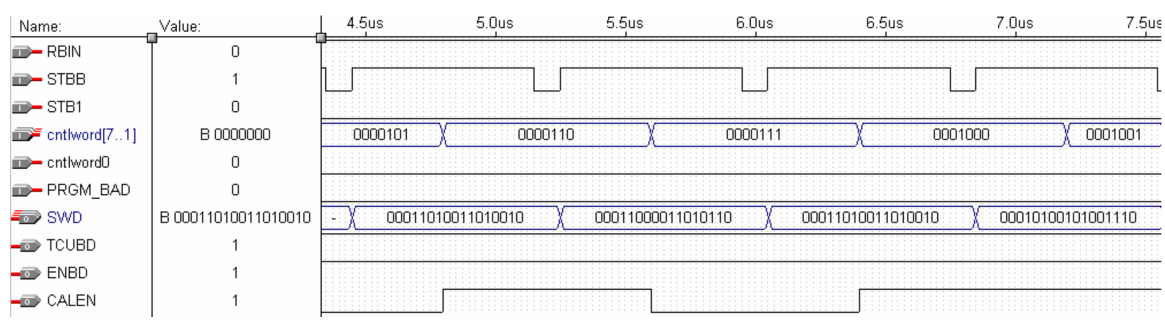


FIGURE 7.7 - Waveform of Extracted Truth Table

To begin the translation process, all the signal names and declarations were altered to support VHDL syntax. Once the external structure of the logic had been converted, indirect conversion was used on the DFFs. In model conversion from ABEL to VHDL is as follows (Figure 7.8):

```
a_dff.d      = input;           a_dff   : dff port map(  input   ,
a_dff.clk    = clock;                                    clock   ,
a_dff.clrn   = clrn;                                     clrn    ,
a_dff.prn    = prn;                                      prn     ,
output       = a_dff.q;                                  output );
```

FIGURE 7.8 - ABEL DFF (left) and its equivalent in VHDL (right)

One note about ABEL, the inputs to clrn and prn do not have to be specified, as they default to high Figure 7.9 shows the actual ABEL code for the D-Flip Flops.

```
(SW1,SW2A1,SW2A2,SW2B2,SW3A1,SW3A2,SW3B2).clrn = global(RBIN);
(SW8,SW9,SW11).clrn = global(RBIN);
(SW2A3,SW2B1,SW2C,SW3A3,SW3B1,SW3C,SW10).prn = global(RBIN);

(SW1, SW2A[1..3], SW2B[1..2], SW2C).clk = global(STBB);
(SW3A[1..3], SW3B[1..2], SW3C).clk = global(STBB);
(SW[8..11]).clk = global(STBB);

(SW1, SW2A[1..3], SW2B[1..2], SW2C).d = swd[1..7];
(SW3A[1..3], SW3B[1..2], SW3C).d = swd[8..13];
(SW[8..11]).d = swd[14..17];
```

FIGURE 7.9 - D-Flip Flops for the Truth Table pin-outs in ABEL

The DFF model was applied to the code in Figure 7.10 and the translation resulted as is listed in Figure 7.11.

```
dff_SW1   : dff PORT MAP (swd( 1), STBB_G, RBIN_G,   HIGH,   SW1);
dff_SW2A1 : dff PORT MAP (swd( 2), STBB_G, RBIN_G,   HIGH, SW2A1);
dff_SW2A2 : dff PORT MAP (swd( 3), STBB_G, RBIN_G,   HIGH, SW2A2);
dff_SW2A3 : dff PORT MAP (swd( 4), STBB_G,   HIGH, RBIN_G, SW2A3);
dff_SW2B1 : dff PORT MAP (swd( 5), STBB_G,   HIGH, RBIN_G, SW2B1);
dff_SW2B2 : dff PORT MAP (swd( 6), STBB_G, RBIN_G,   HIGH, SW2B2);
dff_SW2C  : dff PORT MAP (swd( 7), STBB_G,   HIGH, RBIN_G,  SW2C);
dff_SW3A1 : dff PORT MAP (swd( 8), STBB_G, RBIN_G,   HIGH, SW3A1);
dff_SW3A2 : dff PORT MAP (swd( 9), STBB_G, RBIN_G,   HIGH, SW3A2);
dff_SW3A3 : dff PORT MAP (swd(10), STBB_G,   HIGH, RBIN_G, SW3A3);
dff_SW3B1 : dff PORT MAP (swd(11), STBB_G,   HIGH, RBIN_G, SW3B1);
dff_SW3B2 : dff PORT MAP (swd(12), STBB_G, RBIN_G,   HIGH, SW3B2);
dff_SW3C  : dff PORT MAP (swd(13), STBB_G,   HIGH, RBIN_G,  SW3C);
dff_SW8   : dff PORT MAP (swd(14), STBB_G, RBIN_G,   HIGH,   SW8);
dff_SW9   : dff PORT MAP (swd(15), STBB_G, RBIN_G,   HIGH,   SW9);
dff_SW10  : dff PORT MAP (swd(16), STBB_G,   HIGH, RBIN_G,  SW10);
dff_SW11  : dff PORT MAP (swd(17), STBB_G, RBIN_G,   HIGH,  SW11);
```

FIGURE 7.10 - D-Flip Flops for the Truth Table Pin-Outs in VHDL

Once the structure and flip-flops were converted to VHDL, only the TABLE elements remained. Because of the structured nature of the TABLE construct, a script was used to read in the TABLEs. Valid VHDL was then generated using the model structure in Figure 7.6. The only place the model did not work was with the assignment of the TCUBD internal output signal. The original designers had taken advantage of ABEL's ability to concurrently assign multiple values to a signal using multiple TABLE constructs in such a way that certain assignments defaulted over others. Because of the nature sequential assignments, a separate else-if statement was created to cover the assignment of the TCUBD signal.

After the VHDL translation was completed, the design was compiled and simulated. Because of the way Altera's MAX+Plus II software implements waveforms, the same waveform file was used on the VHDL.

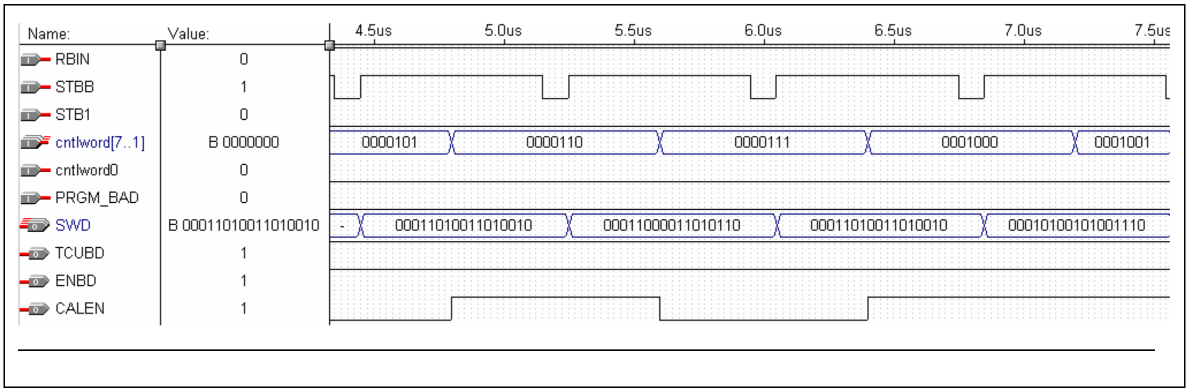


FIGURE 7.11 - Waveform of extracted Truth Table element from VHDL

Figure 7.11 shows the result of the waveform run on the VHDL file the results are the same as in the ABEL file (Figure 7.7).

7.1.7.1 <u>Non-Truth Table</u>

After the Truth Table was extracted and translated into VHDL using our technology and supporting tools, we focused on the remaining sections of the chip, as summarized in Figure 1. These included

- 40 D-Flip Flops organized as a shift register, with 8 bit control words and 11 other control signals
1. A 4 – bit adder
- Three tri-state buffers

These design artifacts were translated into VHDL and the entire design was tested. The test methodology is shown in Figure 7.12, where the original legacy design is compared at every clock cycle with the new retargeted design in VHDL.

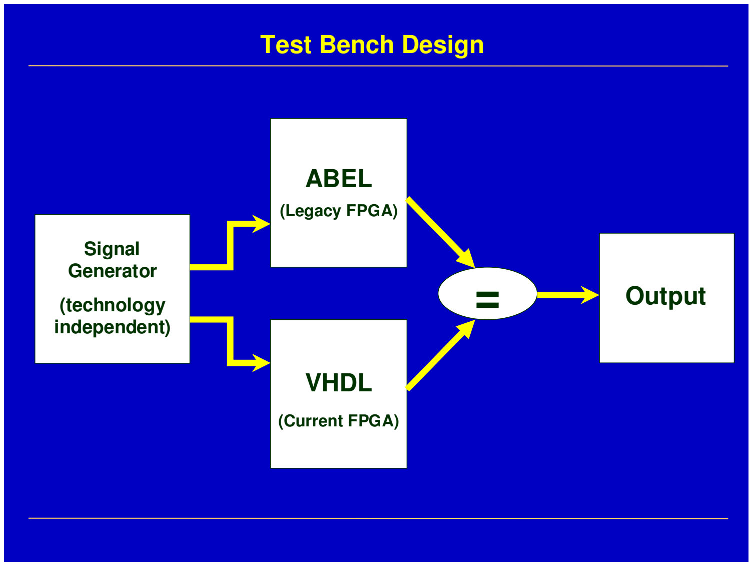


FIGURE 7.12 - Test & Validation Process for the Recovered Design

All possible modes of the design were tested as per the legacy design specification, and they included:

- **Operating Mode -- 256 unique modes**
    - .5 cycle active low strobe
    - 8 cycle active low gated clock w/ 8 bit serial data signal
    - .5 cycle active low strobe
- **Programming Mode -- 2048 unique modes**
    - .5 cycle active low strobe
    - 11 cycle active low gated clock w/ 11 bit serial data signal
    - .5 cycle active low strobe

VP Technologies' VHDL test benches are more robust then the original test bench. The test bench includes the full range of possible inputs and outputs, unlike the legacy test bench, which only tests four possible values per input and output. The final results of the VHDL-based FPGA simulation matched with the original legacy design. This waveform is shown in Figure 7.13, and is identical to the waveform in both operating modes in the original specification.

One design artifact was that the new design was a few nanoseconds (ns) faster in responding for one signal (5-20 ns, for NAME_cmp) as compared to the 133 ns clock period.

No changes in specifications were seen to result from the increase in clock speed, as this result was due to the increased switching speeds of the newer Altera chips.

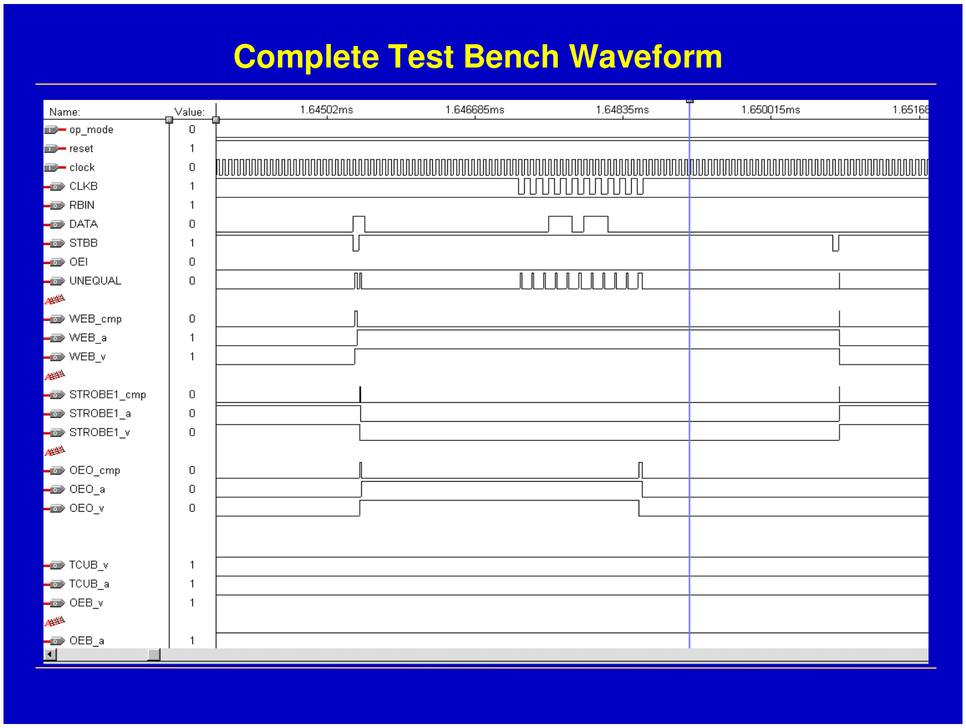


FIGURE 7.13 - Identical waveform for the recovered design

7.1.8 <u>Results Summary</u>

Both functional and timing simulations were run on the ABEL and VHDL files. Functionally both files had the same outputs when provided the same inputs. The testing was extensive but not complete, as MAX+PLUS II had no way of doing batch testing. For the timing simulations, it was observed that the ABEL file would occasionally generate erroneous data due to static hazards. Figure 7.14 shows one such example:

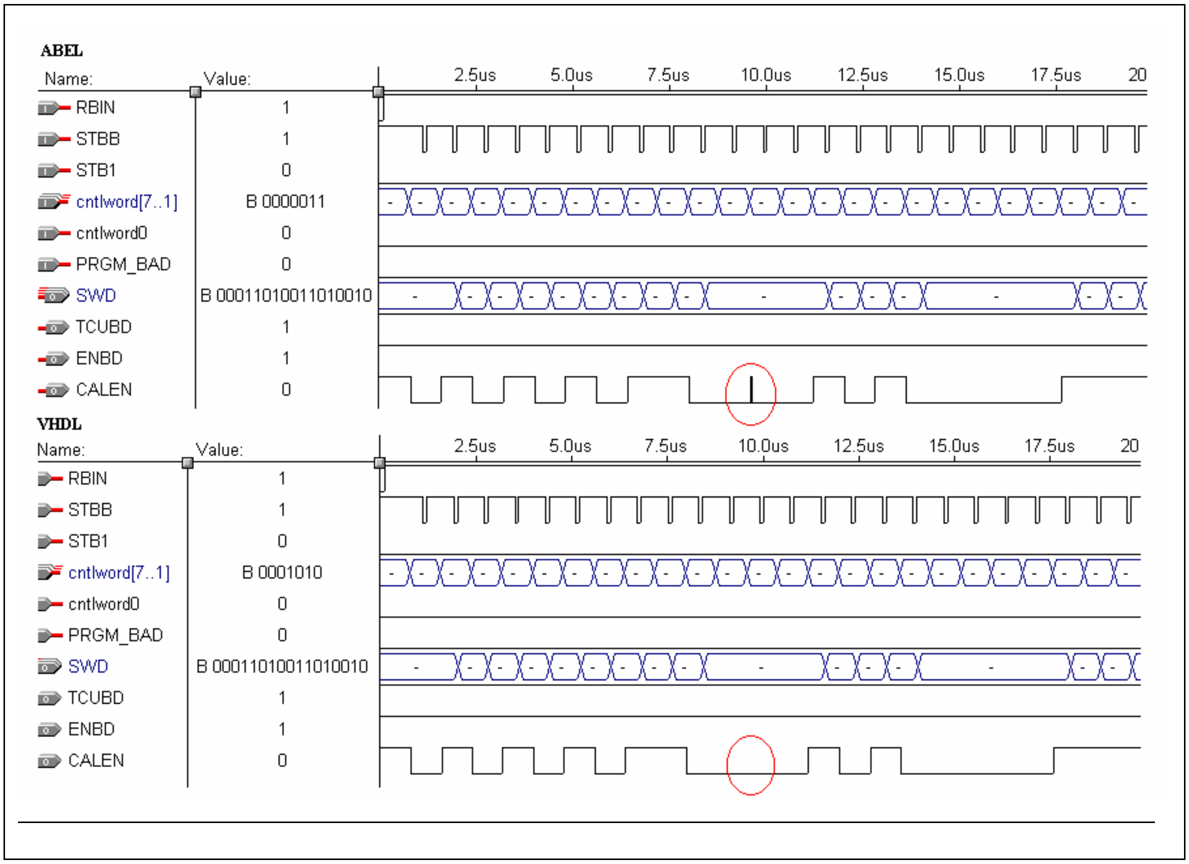


FIGURE 7.14 - ABEL Design Hazard

It is assumed that the brief spike in CALEN in the ABEL waveform was undesirable, as the logic that describes its value does not give itself to such behavior. Furthermore, the spike was not present in the functional waveform. In addition, the rise and fall time of the VHDL were slightly faster than the ABEL implementation by about 8 ns. However, the Hybrid uses a clock slow enough that 8 ns is negligible. The final percentage of the chip used for the ABEL Truth Table was 47%; the final percentage of the chip used for the VHDL Truth Table was 51%. The increased size of the VHDL implementation was attributed to the use of process statements to implement the TABLE structures. The increase was considered nominal.

7.1.9 <u>Design Conversion Benefits</u>

The time saved by using model-based methodology was significant. The six TABLE constructs represented 215 output sets. Those 215 output sets required nearly 1200 lines of VHDL Else-If statements and assignments. The script allowed for quick and reliable generation of the said VHDL and also allowed mistakes to be fixed easily. In addition, larger and more complex ABEL TABLE statements could be converted to VHDL using the same scripting. Using MAX+PLUS II for the new VHDL design also improved efficiency. Any waveform tests used on the ABEL design could be used on the VHDL design with no conversion. In that way testing was efficient and precise.

7.1.9.1 Methodology

Compared to typical manual approaches to design recovery, translation, re-hosting, and test, VP's automated approach has the following benefits.

Increased productivity: The design translations for similar chips (in ABEL) can be completed at the rate of about 50 lines per hour. Thus similar designs for the Longbow can be translated in weeks, as opposed to months by current practice. This should be valid assuming similar logic.

Availability of new tools: The program resulted in a tool that applies PHM to ABEL, and this tool can easily be extended to other coding styles and methodologies for design recovery and translation through addition of new templates.

Correct by construction: The translated code was correct by construction, resulting in zero errors after the design recovery. This cannot be said of manual translation processes.

The proposed methodology and technology has the potential of speeding up the redesign and retargeting of legacy designs in ABEL by a factor of 3-5 over current manual approaches. The disadvantage is in the overhead required when developing models of the underlying behavior for newer circuits, prior to translation.

7.1.9.2 Issues

The Input/Output (I/O) pins are not in the required order. It appears to be a random choice by the FPGA synthesis tool (MAX Plus). The I/O pins are not in the required physical locations either (same side, near a corner etc.) The power and grounds are wrong in pin number and location. This issue was a result of miscommunication on Lockheed Martin's part to VP Technologies. The issue has been resolved to the satisfaction of both parties.

JTAG pins have been added to the model, which was not part of the legacy design. By adding the JTAG to the model the chassis is required to terminate the signals within the chassis, which does not exist. Without this capability to ground/terminate these signals the Hybrid could case damage to the overall system.

There are differences in the simulation results between the original and translated design; these are most likely timing issues. The signal NAME_cmp does not match the original timing simulation. The signal is different by 5-20 ns depending upon the chip mode. Signals, which do not match on a particular vector, are identified. However, one difference was a correction of a problem that was inherent to the ABEL code. For the timing simulations, it was observed that the ABEL file would occasionally generate erroneous data due to static hazards. Finally, as addressed previously, it was assumed that the brief spike in CALEN in the ABEL waveform was undesirable since the logic did not lend itself to this behavior.

7.1.10 Cost Analysis

Comparing VP Technologies to current in-house practices at Lockheed Martin and to other commercial remanufacturers has shown cost and timesavings, as well as higher costs and longer times when compared to other commercial industry practices.

For example: the LMC in-house practice of manually transferring the legacy design to a new design proved to be less cost effective. VP Technologies' use of their more automated approach produced a 39 percent time savings. Along with this reduction in time there was also a reduction in cost by 15 percent over Lockheed Martin's current practices, as shown in figure 7.15. Both VP and Lockheed Martin have about the same price, however VP Technologies can produce the chip in less time than Lockheed Martin. VP Technologies reduced the time to market by 37 percent.

Comparing VP Technologies to an outside remanufacturer such as Company A (which is the commercial company that was contracted to redesign the Longbow FPGA) the total cost to have the redesign was almost identical between the two companies. However, VP Technologies' approach reduced the time to recreate the design model by 16 percent. VP Technologies did not fair as well against Company A in cost or time to market. The cost of VP's design alone was 27 percent higher (not including sample parts). Along with the cost, VP's time to market is 24 percent longer.

7.1.10.1 Cost/Benefit Issues

The numbers are a little misleading when comparing VP Technologies' independent model to Lockheed Martin and COMPANY A. Both Lockheed Martin's and COMPANY A's models are technology dependent. Lockheed's model includes place and route, simulation, and extracted timing while COMPANY A's model includes ten prototypes. Included in the cost and time was the process of producing the chip. However, COMPANY A did slip schedule by six weeks. This slip caused Longbow to secure other die from Altera at a significant cost to the program. This should not considered a loss by the program since the chips were used in the production of the missile. However, this was an added cost that the program did not plan on having and, with the use of VP's independent model, Longbow would at least have had the option of going to a different foundry to have the chips produced. They would have had to pay an extra $5000 – 10,000 dollar charge, but far less than the cost of extra die.

The comparison of the dependent models is a true comparison of all parties involved. However, there are additional issues in this as well. VP Technologies included a one time charge of $22,000 for software to the total cost of the model. Without this charge the savings would have been greater with a 7 percent reduction over the commercial company's cost, and a 20 percent savings over Lockheed Martin's. This is another risk of using a non-established and small company; as they do not have the capital funding or customer base to be able to spread the cost of software over many customers.

Company	Cost	Time (days)	Comments
VP Technologies	**$49,900.00**	55	**Technology Independent Model (no software charge)**
	$58,000.00	40	**Technology Dependent Model (Includes $22 K in software)**
	$10,000.00	40	**Ship GDS to AMI (foundry work)**
		5	**Test chip**
	$68,000.00	85	**This is for chip and model (technology dependent).**
Company A	**$49,500.00**	65	**Technology Dependent Model and 10 prototypes**
	$149,500.00	30	**Slip on shipment of chips. This caused Longbow to purchase $100 K in chips from Altera.**
		95	**Total cost and schedule**
Lockheed	**$57,600.00**	90	**Technology Dependent Model includes GDS file**

Figure 7.15 – VP / Longbow Pilot Summary Cost Analysis

7.1.11 Summary

The Longbow FPGA to ASIC conversion soft pilot allowed Lockheed Martin to compare VP Technologies to Lockheed Martins and other commercial companies' practices in an effort to evaluate VP's claim to reduce development cost and time by a one third.

The original design translated well using VP's PHM technology. The legacy circuit descriptions were mapped to parametric models (e.g. state machines or other logical structures) and converted to a technology independent form of VHDL. Therefore, the greatest benefit of VP Technologies' approach is through the use of PHM which allowed for increased productivity by automating the translation of the legacy code. The translated code was correct by virtual design, testing, and construction it resulted in zero errors after the design recovery. This cannot be said of manual translation processes. It was proven that the proposed methodology and technology has the potential of speeding up the redesign and retargeting of legacy designs in ABEL by a factor of 3-5 over current manual approaches. The overhead is in developing models of the underlying behavior for newer circuits, prior to translation.

Disadvantages however of using VP Technologies must be understood. This primarily the cost of recapturing the design since VP's price for a technology independent model was as much as the commercial company that won the contract. The difference being that Lockheed Martin received 10 prototype dies from the commercial company. The only deliverable VP provided was the model. Unfortunately, VP's original bid to perform the contract was the second highest among the six commercial companies that submitted bids. The only higher bidder planned to radiation harden the chip, which is more expensive to produce.

VP's time to market would have been greater than all of the other companies that bid on the contract (45 percent higher then the next highest bidder) primarily due to VP having no foundry. If the original redesign bid had been won by VP, they would still have had to send the design out in order to have it fabricated. This would have taken up 68 percent of the time required to get the product to the customer.

It must be noted however, that VP's model was technology independent and was the intellectual property of Lockheed Martin. The cost and effort of redesigning this model again in the future was replaced by making it independent, but at a higher initial cost.

7.2 Boeing / Hellfire Pilot

The purpose of the Boeing Hellfire Video Preamplifier Technology Pilot was to retarget the Lockheed Martin Hellfire Missile's Automatic Gain Control Pre-Amp ASIC for the MTADS Program. Boeing's Small Scale Electronics Division would evaluate their use of the Orora and Neolinear toolsets and the flexible foundry relationship they established with DMEA.

FPGA designs face a typical obsolescence problem which is: Even if there is a replacement FPGA available from the manufacturer some modifications to the original code may be required. Other issues such as a different footprint or timing variations can create significant problems as well. If a suitable replacement is not found the designs must often be ported to an ASIC because of design constraints. Many of these ASIC solutions are very expensive, not just in non-recurring engineering costs, but also in potential system re-qualification and production delay costs.

Most obsolescence strategies will not work for components that are custom designs because of the lack of Commercial-Off-The-Shelf (COTS) replacements available. Many assemblies require a design specific ASIC. These originally took a long period and significant funding to develop. Additionally, during efforts to procure the parts from the original foundry, other issues occur including: the process that the part was developed with has gone obsolete, or the foundry doesn't want to produce such small quantities, or it no longer has the technical knowledge or expertise to recreate the process, or they may not even be in business. Finally, the non-recurring engineering and re-qualification costs associated with these parts are very high and the lead time needed to perform the modifications can require several years before availability.

Boeing has developed a flexible foundry agreement with several foundries to reduce the cost of fabricating small quantities of die. Boeing also worked with the University of

Washington to help develop and test the Orora and Neolinear tools. These tools are used to port a legacy ASIC into new technology and automate the layout process to reduce time and risk.

With the use of data provided by Lockheed Martin Hellfire program, Boeing exercised the flexible foundry and tools to target a new foundry process. Boeing combined simulation of design constraints and use of the automatic place and route Neolinear tool in this new process.

While including the technology pilot, Lockheed Martin has captured data to help evaluate possible cost and risk associated with using Boeing's flexible foundry and the tools for retargeting the Hellfire Pre-Amp ASIC.

7.2.1 Boeing's Capabilities

Boeing's Solid State Electronics Development is one of the leaders in the military industry for mixed signal designs. To date Boeing has developed over 450 ASICs including designs in: digital, analog, RF, and mixed signal. These designs have been implemented in commercial applications such as: Boeing's 700 series aircraft and high speed civil transportation. As well as many defense applications: Comanche Helicopter, AWACS, and F22 Raptor. For the Hellfire Study Lockheed Martin is leveraging Boeing's Commercial ASIC Design Center developed under the Air Force Research Laboratories (AFRL) ManTech's Application of Commercially Manufactured Electronics (ACME) and Defense MicroElectronics Activity (DMEA) programs flexible foundry concept and automated layout tools.

The Flexible Foundry concept has been developed to support obsolete higher voltage semiconductors that commercial industry has abandoned in the pursuit of newer technologies of 3.3V and lower. The program was implemented after the commercial semiconductor industry made the understandable and justifiable business decision to no longer produce parts for the low-volume, long-product-cycle military market. As a result to cost considerations, the Department Of Defense (DoD) is not ready to redesign a majority of their weapon systems to accommodate the newer low-voltage parts.

Orora Design Technologies Inc. and the University of Washington have developed an automated computer-aided design (CAD) layout toolset that helps circuit designers to analyze and visualize how analog, mixed signal and RF circuits and systems are affected by device, process, and parasitic parameters across multiple abstraction levels during both the design and diagnosis stages.

7.2.2 Lockheed Martin's Capabilities and Needs

Lockheed Martin's current method for handling an obsolete ASIC is to first see if the device can be obtained from the original supplier. If the supplier is still in business, Lockheed Martin will contact them to determine if the supplier still uses the original process. If not, the second solution is to determine if they have a comparable process to port the device to. However, this usually not the case and a new process will require significant changes to the original design. If the original foundry is no longer in business or they don't have a comparable process, Lockheed Martin has restricted alternatives: redesign the ASIC using a new technology or new foundry, or contract a third party to redesign the ASIC.

Sometimes the solutions are complicated by the amount of data available for the component. In this case, Lockheed Martin has the electronic files for the layout and data used to produce the ASIC. Regrettably, some designs are limited to Lockheed only having a schematic or requirement documents, which complicates the issue since the original foundry and process may not be known.

7.2.3 Pilot Objectives

The objective of the Boeing pilot is to exercise the flexible foundry, Neolinear toolset, and leverage Boeing's expertise in mixed signal design for redesigning the Hellfire Pre-Amp. Boeing will make a recommendation on a target foundry, process, cost, and schedule for full scale development. They will also combine risk analysis based on data provided.

7.2.4 Boeing's Tools

Orora Design Technologies Inc. and the University of Washington have developed an automated computer-aided design (CAD) layout toolset that helps circuit designers to analyze and visualize how analog, mixed signal and RF circuits and systems are affected by device, process, and parasitic parameters. This study goes across multiple abstraction levels during both the design and diagnosis stages.

The two tools used for the study are NeoCell and NeoCircuit. See Figure 7.16 below.

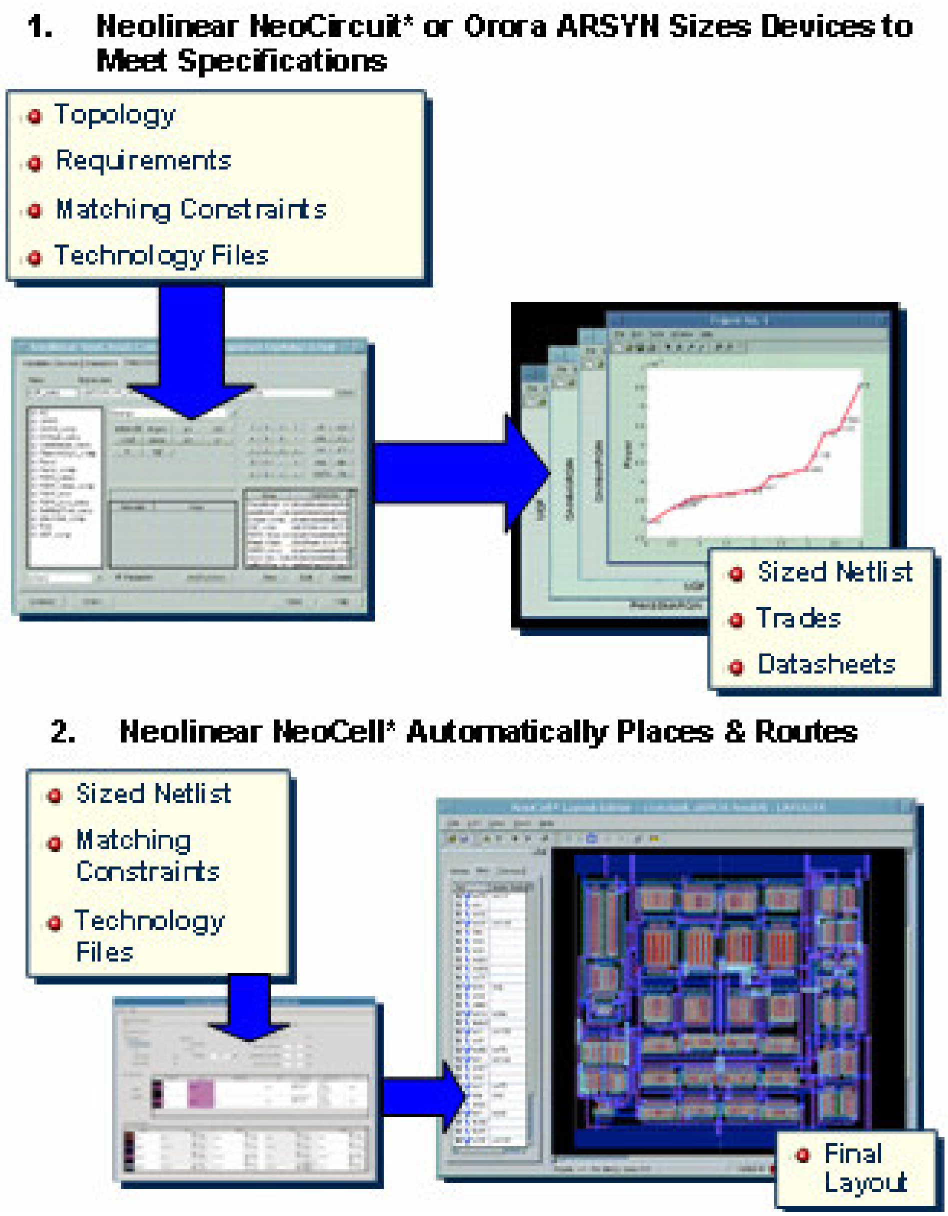


Figure 7.16 - Neolinear Tools Process Flow

7.2.4.1 NeoCircuit

NeoCircuit allows the designer to pull in libraries from the target foundry's processes and implement these libraries to the design. The user can specify topology requirements for the design to determine the effect on the outputs. Along with topology the user can specify design requirements such as: component size, keep out areas (for possible issues: EMI, heat, packaging, etc.), timing, overall component die size, etc. This allows the designer to complete trade studies by picking components from the library and test the design using specified constraints to verify the design. The output of the tool is a sized netlist (component and device sizes), matching constraints, and technologies files, which are inputs to the NeoCell tool.

7.2.4.2 NeoCell

The NeoCell tool uses the outputs from the NeoCircuit to automatically place and route the die. Since the user has inputted the constraints placed on the components and the die the tool is able to use this information is used to optimize the layout. The user can also go in and change the layout in areas if there is any possible issue with the automated layout. Sometimes the optimized layout may not be ideal for the design. Reasons for this dilemma may include: cross talk, noise, hot spots, etc.

7.2.4.3 Flexible Foundry

Boeing's flexible foundry was developed under the Air Force ManTech's Electronics Parts Obsolescence Indicative (EPOI), ACME, and DMEA. Flexible Foundry has been implemented to support obsolete high voltage semiconductors which the commercial industry has abandoned in the pursuit of newer technologies of 3.3V and lower. The program was implemented after the commercial semiconductor industry made the understandable and justifiable business decision to no longer produce parts for the low-volume, long-product-cycle military market.

7.2.5 Video Preamplifier

The Pre-Amp is a four-channel, low noise, wide dynamic range, video pulse trans-impedance amplifier. A minimum of 80 dB automatic gain control range is featured which allows the amplifier to remain in its linear region throughout the input dynamic range of 50 nAp to 100 mAp without signal saturation or clipping.

Each of the four channels contains a trans-impedance (current to voltage) video pulse amplifier, an attenuator ladder circuit, and a gain control circuit. All four channels share the first and second AGC driver circuits. Although thermal symmetry considerations would require separate AGC drivers for each channel, the implementation of a common AGC driver was chosen due to packaging constraints on die size. The die is package in a hybrid circuit provided by Lockheed Martin and implemented in the Hellfire video seeker assembly.

The Pre-Amp die is required to meet the following:

System/Amplifier stability 30+ degrees of phase margin in amplifier
Amplifier performance 15 MHz 3 dB Band Width ± 1.5 dB gain peaking
Depth of attenuation for the entire circuit 80 + dB requirement from electrical specifications matrix
Pulse transfer functions matching Ztra = original small pulse test and Ztrb = original large pulse test
Linear input range 50 nAp – 100 mAp
Overload recovery max overload of 1000 mAp
Layout size must match original footprint and pad structure

Max current draw/ Max power 1.5 W, 70 mA positive supply, and 80 mA negative supply
AGC voltage range +0.5 to -13 absolute and 0 V to -10 V specified under operation
Dielectrically isolated

7.2.6 Foundry Results

Boeing identified two possible foundries for implementation of the Hellfire Pre-Amp design. Both Legerity's and Intersil's processes are adequate to meet the design performance for the Pre-Amp die see Figures 7.17 and 7.18.

Device Performance Comparison				
	Original	**Legerity**	**EBHF**	**Units**
NPN, Beta (BF)	270	94	270+	
NPN, VAF	115	1403	286+	V
PNP, Beta (BF)	90	72	170+	
PNP, VAF	60	495	90+	V
Resistor Variance				
Res* **	+/- 15% (Ion Implanted Boron)	+/- 10% (hi-res poly)	+/- ?% (ni-chrome)	

*** *These are the main resistor options. Diffusion resistors are available as well in each process.*

Figure 7.17 - Device Performance Comparison

Device Size Comparison				
	Original	Legerity	EBHF	Units
NPN	9400-18000*	1150-2400**	7100-9100**	um2
PNP	9400-18000*	1150-2400**	6600-8600**	um2
Cap	Approx .33*	.392	.339	fF/mm2
		.099	.305	fF/mm2
Res***	850-1150 Ion Implanted Boron – Precision – Tempco like diffused	1000 (poly)	200 (ni-chrome)	Ohms/ Sq
		145 (poly)		Ohms/ Sq
Diff Res	n+, n-, p+, p-	none	N+, p+, p-, p- -, ebhrps	

* *Sizes extracted from layout picture*
** *Based on sizes used in simulations. For EBHF, low values are process minimums.*
*** *These are main resistor options. Diffusion resistors available as well in each process*

Figure 7.18 - Device Size Comparison

7.2.6.1 Intersil Semiconductors

Intersil (formally Harris Semiconductors) produced the original Pre-Amp die, but the process used has become obsolete. Intersil's EBHF process has been targeted for developing the new design. Boeing has used this process before on the following programs: F-22 Power Supply Monitor ASIC, F-15 HUD LM1648 VCO, and F-15 HUD MC1595 Video Amplifier. This process is supported by DMEA flexible foundry program.

Key Process Characteristics were:

- Dielectrically isolated
- Complementary bipolar process
- High gain NPN and PNP transistors
- Adequate breakdown voltage
- Diffused and thin film resistors
- Metal-metal capacitors

Boeing performed simulations using Intersil's EBHF simulation engine with the use of the Orora toolset. The simulation allows Boeing to use library specific information to populate the SPICE model and to verify the design assumptions being made. Some of the assumptions being made are transistor, resistors, and capacitor type and sizes. Difference in any one of these can cause unwanted changes in the output that can cause the device not to meet the design specifications. The simulation also allows Boeing to test the upper and lower limits of the design, and temperature testing can be simulated as well. The advantage of doing this is it gives the designer real-time feedback on changes being made without having to incur the cost of a fabrication run. Boeing used the SPICE model and test benches provided by Lockheed Martin to compare their design to the original design. Figure 7.19 shows one of the outputs from the simulator verses the original design simulation.

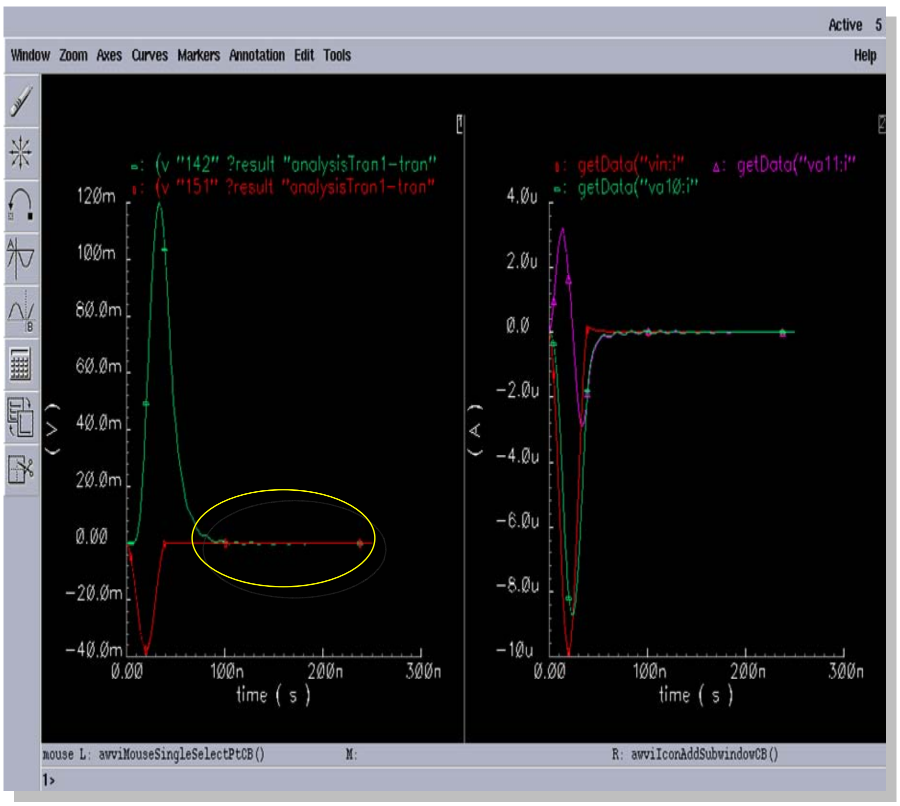


Figure 7.19 - 10 uAp Pulse

7.2.6.2 <u>Legerity Semiconductors</u>

Legerity Semiconductors (originally AMD Communications Products Division) is a commercial foundry with a background in the communication industry. Legerity has been a major supplier of semiconductors for Lucent, Siemens, NEC, and several Chinese companies. Boeing is targeting Legerity's HV-8 process to develop the Pre-Amp die.

Key Parameters:

- Dielectrically isolated
- Complementary bipolar process
- Trench isolation
- Small minimum transistor size
- 8 inch wafer – low die cost
- High breakdown voltage
- Poly resistors
- Metal-poly capacitors

Boeing performed simulations using Legerity's HV-8 simulation engine. The simulation allows Boeing to use library specific information to populate the SPICE model and to verify the design assumptions being made about the design. Boeing will match perform the same test that they used in the Intersil simulations discussed in the above section. Figure 7.20 shows one of the outputs from the simulator verses the original design simulation.

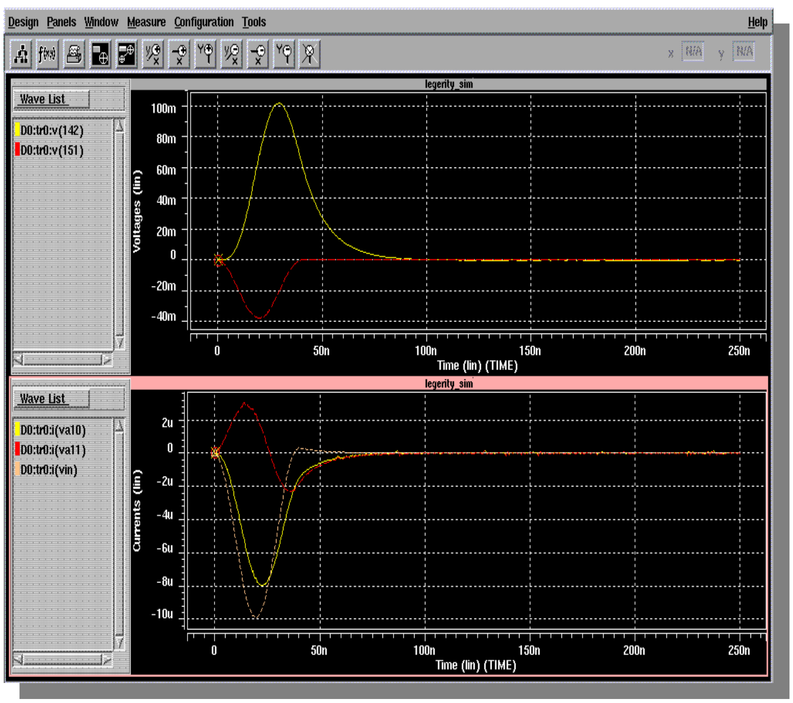


Figure 7.20 - 10 uAp Pulse

7.2.7 Cost Estimates

In order to estimate and compare costs between the two approaches cost values were collected and are presented in the following sections.

7.2.7.1 Intersil

To produce a fabrication run requires a minimum of 10 wafers for a total of 4700 untested die, which can be split into two sets of 5 wafers each. The reason Lockheed Martin may want to run a split run is to be able to make changes to the remaining wafers if the first die does not meet specifications without incurring the cost of a full fabrication run again.

Non Recurring Engineering (NRE) and Fabrication cost:

NRE	$16K
Mask NRE	$60K
10 Wafer Fab.	$50K
Split Lot Fee	$5K
Total Cost	$131K

Cost to complete 5 wafers previously held at metal is $18K. Die cost for future orders is $50K per 4700 die or $10.64 per die. Extra cost will be incurred if Lockheed Martin wants die testing done at Intersil.

7.2.7.2 Legerity

To produce a fabrication run requires a minimum of 12 wafers for a total of 25,200 untested die, which can be split into two sets of 6 wafers each. The reason Lockheed Martin may want to run a split run is to be able to make changes to the remaining wafers if the first die does not meet specifications without incurring the full fabrication run again. Legerity offers a multi-project run which provides 50 die for engineering testing to verify the design at a cost of $63K.

Non Recurring Engineering (NRE) and Fabrication cost:

NRE	$30K
Mask NRE	$135K
12 Wafer Fab.	$55K
Split Lot Fee	$0K
Total Cost	$220K

Cost to complete 6 wafers previously held at metal is $18K. Die cost for future orders is $55K per 25,200 die or $2.18 per die. Extra cost will be incurred if Lockheed Martin wants die testing done at Legerity.

7.2.7.3 Boeing

Boeing's design flow is shown in Figure 7.21. Note that the steps in blue are optional tasks that would be performed only if Lockheed Martin requests them.

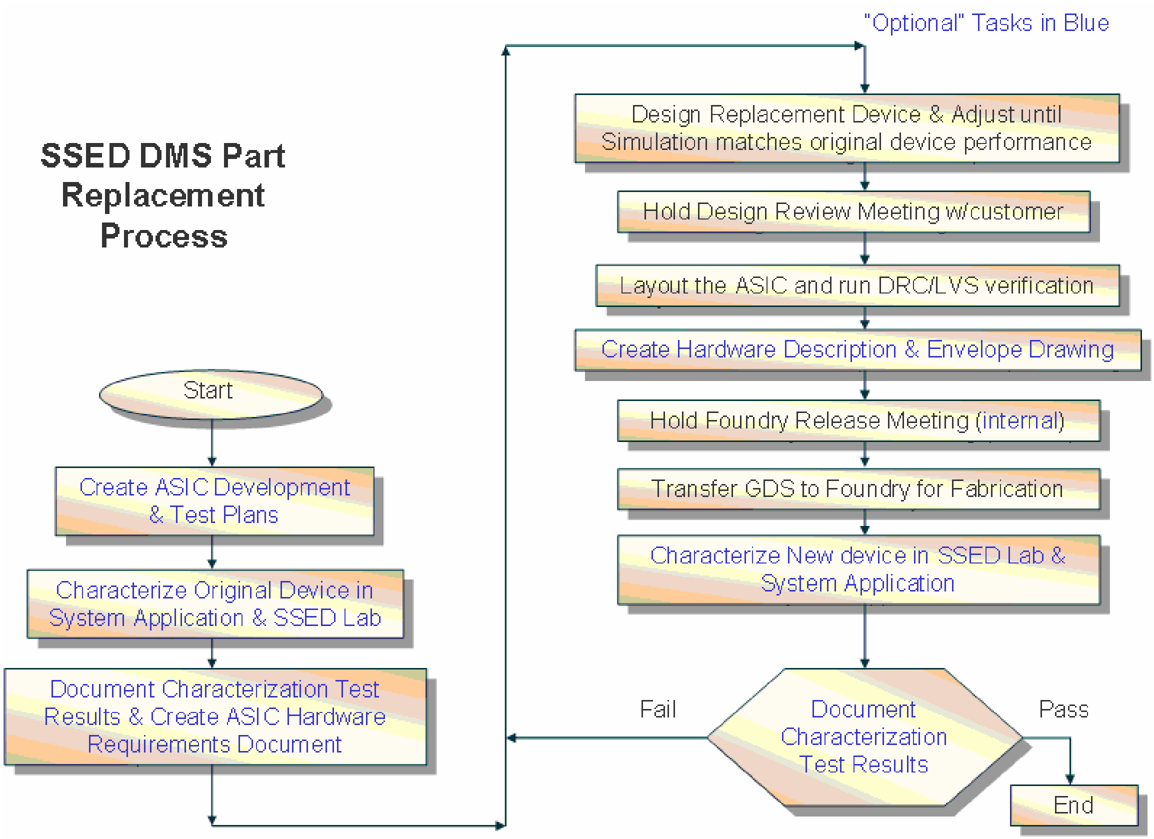


Figure 7.21 – Part Replacement Process

For the Intersil costs, Boeing provided the cost and schedule data to perform the redesign without the options shown in blue which includes Boeing's hours to complete the design work and all cost and schedule data.

- 1 Design Engineer (no test or documentation)
- 913 Total Hours if first pass success
- 1169 Total Hours if second pass needed
- 10 Month Schedule if first pass success
- 15 Month Schedule if second pass needed
- Fabrication Cost $131K first pass (4700 die)
- If Second pass metal mod $18K (2350 die)
- If Second pass requires full fabrication, cost is $131K (4700 die)

This data includes the optional tasks.

- 1 Design Engineer & 1 Test/Documentation Engineer
- 3,021 Total Hours for two passes
  (2300 if first pass success)
- 11 Month Schedule if first pass success

- 15 Month Schedule If metal second pass
- 17 Month Schedule if full second pass
- Fabrication Cost $131K first pass (4700 die)
- Second pass metal mod $18K (2350 die)
- If Second pass requires full fabrication, cost is $131K (4700 die)

For the Legerity costs, Boeing also provided the cost and schedule data to perform the redesign without the options shown in blue (including Boeing's hours, costs, and schedule data).

- 1 Design Engineer (no test or documentation)
- 1,249 Total Hours
- 17 Month Schedule
- Multi-project Fab Cost $63K (50 engineering use die)
- Dedicated Fab Cost $220K
- Deliver Approximately 25,000 untested die

This data includes the optional tasks.

- 1 Design Engineer & 1 Test/Documentation Engineer
- 3,061 Total Hours
- 17 Month Schedule
- Multi-project Fab Cost $63K (50 engineering use die)
- Dedicated Fab Cost $220K
- Deliver Approximately 25,000 untested die

7.2.8 Risk Analysis

Boeing performed risk analysis as part of the study and have identified areas of concern for both foundries.

7.2.8.1 Intersil

In the simulation runs that have been performed for the study the EBFH process has an apparent oscillation in one transistor circuit of the design. Boeing has found that adjusting the feedback loop in this circuit reduces that oscillation, but they have not completely resolved this issue. Boeing has informed Lockheed Martin that the oscillation could be a modeling issue with Intersil's simulator. In the past Boeing has had an issue with the EBHF simulator. One suggestion is to model the circuit in HSPICE and re-run the simulation to verify the oscillation. If the oscillation continues Boeing will have to move to a different process or company.

7.2.8.2 Legerity

Boeing has determined that Legerity is the preferred foundry from a technical and cost standpoint. However, Legerity does all its foundry work outside the United States which posses a International Traffic in Arms Treaty (ITAR) issue, because the design will be sent to one of these off-shore foundries. To work around this issue is for Legerity to work a deal with a foundry inside the United States to produce the die.

7.2.9 Boeing Pilot Summary

The Hellfire Study has shown a weakness in Boeing's flexible foundry, since neither Legerity nor Intersil belong to the consortium. When Boeing did a search for dielectrically isolated bipolar processes only Intersil and Legerity met the requirements. As a result of the study, Boeing has approached DMEA about having Legerity evaluated as a possible addition the flexible foundry.

One notes however, that an EBHF process was developed under the DMEA contract and is supported under the flexible foundry agreement. As part of the agreement Intersil ported a legacy process to current CAD tools to allow the military to continue using the process.

Boeing also did not completely exercise the Orora toolset because of time constraints on the study. The tools were used with generic values to verify that both Intersil and Legerity's processes would meet the size constraints of the design. This procedure was done by loading each company's libraries into the tool and picking components close to the sizes that Boeing felt would meet the performance requirements. The tool then laid out the components to verify they would fit in the die size.

7.3 MTADS / MOCA Pilot

The purpose of the MTADS/MOCA Technology Refreshment Planning Technology Pilot is to evaluate the Mitigation of Obsolescence Cost Analysis (MOCA) software tool developed by the University of Maryland Computer Aided Life Cycle Engineering (CALCE) center.

The rapid growth of the electronics industry has spurred dramatic changes in electronic parts. Increases in speed, reductions in feature size and supply voltage, and changes in interconnection and packaging technologies are becoming events that occur almost monthly. Consequently, many of the electronic parts that compose a product have life cycles that are significantly shorter than the life cycle of the product. This life cycle mismatch problem requires that during design, engineers be cognizant of which parts will be available and which parts may be obsolete during a product's life. This problem is especially prevalent in avionics and military systems, where systems may encounter obsolescence problems before being fielded and nearly always experience obsolescence problems during their field life. Manufacturing, that takes place over long periods of time, exacerbates this problem, and the high cost of system re-qualification that makes the design refreshes extremely expensive.

Many part obsolescence mitigation strategies exist including: life time buy, last-time buy, part replacement, aftermarket source, up rating, emulation, re-engineering, salvage, and ultimately redesign of the system. Design refresh (or redesign) has the advantage of treating multiple existing and anticipated obsolescence problems concurrently and additionally allows for functional upgrades. Unfortunately, design refresh is also often a very expensive option, not just in non-recurring engineering costs, but also in potential system re-qualification costs.

The University of Maryland's (UMD) Computer Aided Life Cycle Engineering (CALCE) Center has developed the Mitigation of Obsolescence Cost Analysis (MOCA) software tool to determine the optimum design refresh plan as a function of forecasted parts obsolescence events and production distributed over time.

With data provided by the Lockheed Martin Modernized Target Acquisition Designation Sight (MTADS) program UMD used their MOCA tool to forecast the optimum design refresh date(s), the risk(s) associated with the forecast, and provide suggestions based on the data used.

With the technology pilot Lockheed Martin has captured data to help evaluate possible refresh dates due to parts obsolescence. Along with the refresh dates the pilot will evaluate the risk(s) involved with current program schedule due to parts obsolescence. The pilot also allowed Lockheed Martin to exercise the i2 Life Cycle Management (LMC) tool, which is also part of the POMTT charter.

7.3.1 MOCA – University of Maryland

MOCA represents the first methodology for part obsolescence driven design refresh scheduling and optimization. Based on a detailed cost analysis model, the methodology determines the optimum design refresh plan during the field-support-life of the product. The design refresh plan consists of the number of design refresh activities and their respective calendar dates and content to minimize the life cycle sustainment cost of the product. The methodology supports user determined short and long-term obsolescence mitigation approaches on a per part basis, variable look ahead times associated with design refreshes. Part obsolescence mitigation strategies can be compared to design refreshing part obsolescence elimination strategy.

Proactive life cycle planning, such as MOCA, provides a program manager with the ability to predict as early as possible (ideally during the design phase), what the sustainment costs are going to be and how to best plan design refresh budgets and content. The specific payoff is an ability to forecast optimal design refresh points (and the content of the refresh) which enables significant cost avoidance via:

More accurate allocation of budget earlier in the program development phase
More accurate guidelines for how systems are modified at design refreshes
Improved operational availability
More optimal obsolescence mitigation approach decisions
Enables the opportunity for shared solutions across systems and applications

7.3.2 Lockheed Martin OM Cost Analysis Practices

Lockheed Martin's current practice for parts obsolescence is reactive. Programs will schedule redesigns or technology refresh based upon contractual dates or past practices. Managing parts obsolescence is done several different ways: using existing stock (this could be supplied by other programs), negotiating with manufacturer, last time buy (when the part starts to go obsolete buy only the amount needed to complete contract), lifetime buy (buying all the parts at the beginning of production), alternate part equal, or better than the original part, buy from aftermarket sources, emulate, or redesign. These practices add cost and delays to hardware. In recent years Lockheed Martin has worked to standardize components and look proactively at part selection to choose parts that have a longer life cycle or are early in their life cycle. The only time parts list are checked for obsolescence is when a request for proposal for a new contract. At this time obsolescence is addressed and a plan is implemented to mitigate the obsolescence. If a refresh is needed this will be added into the price and schedule of the new contract.

7.3.3 Pilot Objectives

The objective of the MOCA pilot was to exercise the MOCA tool and to provide a basic forecast of design refresh dates and content for the MTADS Video Processor card. The pilot team used the MOCA tool to forecast optimum design refresh dates, assess risks associated with the forecast and make suggestions based on the data provided.

7.3.3.1 MOCA Tool Methodology

A methodology and its implementation have been developed for determining the part obsolescence impact on life cycle sustainment costs for the long field life electronic systems based on future production projections, maintenance requirements, and part obsolescence forecasts. Based on a detailed cost analysis model, the methodology determines the optimum design refresh plan during the field-support-life of the product. The design refresh plan consists of the number of design refresh activities, and their content and respective calendar dates that minimize the life cycle sustainment cost of the product.

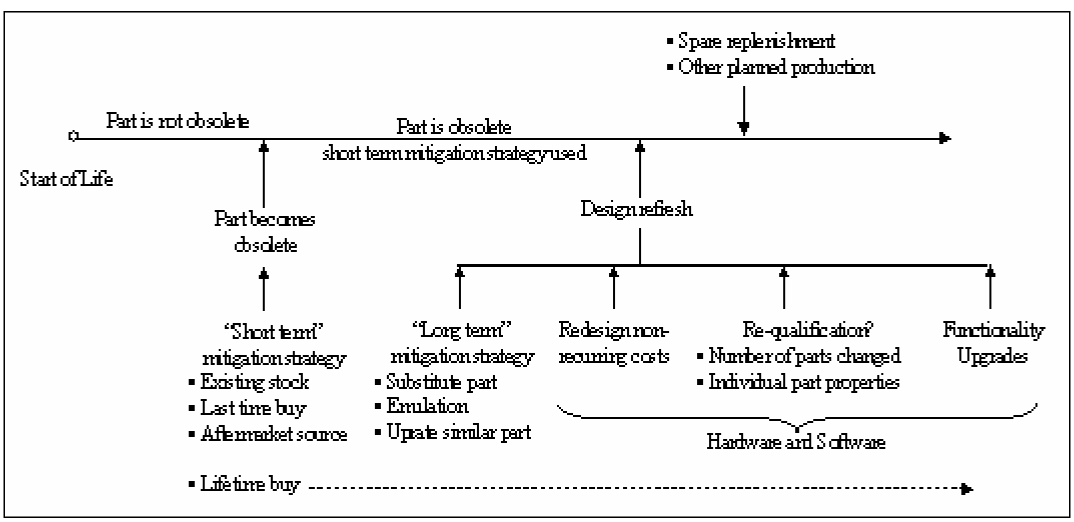


Figure 7.22 - Design Refresh Planning Analysis Timeline

Figure 7.22 shows the design refresh planning timeline. Fundamentally, the methodology must support a design through periods when no parts are obsolete, followed by multiple part-specific obsolescence events. When a part becomes obsolete, some type of mitigation approach must take effect immediately, either a lifetime buy of the part is made or a short-term mitigation strategy that only applies until the next design refresh. Next, there are periods of time when one or more parts are obsolete, lifetime buys or short-term mitigation approaches are in place on a part-specific basis. When design refreshes are encountered (their date is defined either by the user or by the methodology during its optimization process) the change in the design at the refresh must be determined and the costs associated with performing the design refresh must be computed. At a design refresh a long-term obsolescence mitigation solution is applied (until the end of the product life or possibly until some future design refresh), and non-recurring, recurring, and re-qualification costs computed. Re-qualification may be required depending on the impact of the design change on the application – the necessity for re-qualification depends on the role that the particular part(s) play and the quantity of non-critical changes made. If the expense of a redesign is to be undertaken, the most likely functional upgrades will also occur during the redesign. The system functional upgrades must be forecasted and (including forecasting the obsolescence of future parts). All the design refresh activities have to accommodate both hardware and software redesign and re-qualification. The last activity appearing on the timeline is production. The product often has to be produced after parts begin to go obsolete due to the length of the initial design/manufacturing process, additional orders for the product, and replenishment of spares.

The methodology described above supports user determined short- and long-term obsolescence mitigation approaches on a per part basis, and variable look-ahead times associated with design refreshes.

One of the key attributes of the methodology is its treatment of uncertainties. Obviously, much of the data that the method depends on to make design refresh decisions is highly uncertain. In order to solve the problem two types of uncertainties must be managed, 1) uncertainties in the inputs to the cost analysis, for example, the re-qualification cost associated with a particular type of qualification test; and 2) uncertainties in dates. The first type of uncertainty is handled through Monte Carlo modeling. The second type of uncertainty (dates) is more complex to accommodate. At the highest level in the solution, an algorithm that selects a candidate refresh plan is used. A candidate refresh plan consists of the quantity of design refreshes in the lifetime of the product and the dates of those refreshes relative to production events, Figure 7.23. A production event is any event that results in the need to produce additional instances of the product, i.e., additional orders or spare replenishment necessary for sustainment. Once a candidate refresh plan is chosen, an actual sampling of dates for the production events will be chosen (the date for each production event is input as a probability distribution). After the probability distributions for the dates are sampled, a sample refresh plan (with real dates) is available. The methodology then computes the life cycle cost of the candidate refresh plan for the sample. Using a basic Monte Carlo approach, the methodology repeats the process of sampling production dates and computing life cycle costs a statistically relevant number of times producing a histogram of the life cycle costs for the candidate refresh plan.

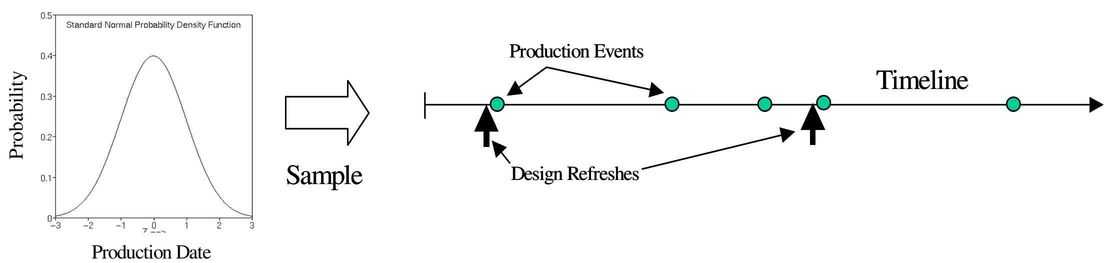


Figure 7.23 - Candidate Refresh Plan

Another important aspect of the algorithm is the identification and use of a time step. Unlike physical simulations, where the smaller the time step chosen for the simulation, the more accurate the answer; in this simulation, too small a time step may be just as inaccurate as too large a time step. The correct time step to use is one that corresponds to the OEMs procurement cycle, i.e., how quickly are part procurement decisions made, vendors approved, and procurements completed (parts in-house and ready for use in products) – normally, we assume times steps on the order of 1-2 quarters. In this methodology, for a given time step size, after the sampled candidate refresh plan is determined, the resulting timeline is dropped onto a grid that corresponds to the time step (each date in the sample is moved to the closest point on the time step grid).

7.3.3.1.1 MOCA Software Tool

Mitigation of Obsolescence Cost Analysis (MOCA) is a software tool developed to enable the prediction of an optimum design refresh plan. Figure 7.24 describes the organization of the MOCA tool.

1. Inputs – The basic input for the MOCA tool is a bill of materials (parts list) corresponding to the system to be analyzed. The critical information included in the parts list is the quantity, price, obsolescence date (see the next section), and qualification impact. In addition to the parts list, the partitioning of the parts onto boards is input. The other classes of inputs are the production plans, i.e., how many of each board are produced as a function of time (both initial manufacturing quantity and any subsequent manufacturing), and the dates of any pre-planned design refreshes.
2. Generate event list – Combine all the events (production, fixed design refreshes, and individual part obsolescence) onto a single timeline called an event list.
3. Determine cost of no refresh case – Determine the effective life cycle cost of the event list with no added design refreshes. The solution

serves as a baseline for the MOCA analysis. In this case obsolete parts are assumed to be either from existing stock, subject to lifetime buys or purchasable in the aftermarket (depending on user preferences on a per part basis).

4. MOCA cost analysis – The MOCA cost analysis determines the life cycle cost of an event list. The non-recurring and the new production costs at design refreshes are computed through an interface to the Price Systems H and HL tools.
5. Choose a candidate design refresh plan – A candidate set of design refreshes (date of each specific refresh) is chosen for analysis.
6. Modify event list – The original event list is modified to include the candidate design refreshes.
7. Synthesize new parts – When parts are replaced at design refresh events, they must be replaced by a newer part that does not exist today. MOCA synthesizes a new part, including forecasting of the obsolescence date for the new part(s).
8. Determine cost of candidate refresh plan – The MOCA cost analysis is used to determine a life cycle cost of the event list containing the candidate design refresh plan.
9. Completed design refresh plans are ranked on the basis of economics – All the candidate design refresh plans considered are ranked and the lowest effective life cycle cost solution is chosen.
10. Price H/HL (commercial LCC tool) – Price life cycle cost analysis tools are used both in the evaluation of specific design refresh plan candidates and to determine the final life cycle cost of the system once a final refresh plan is chosen.

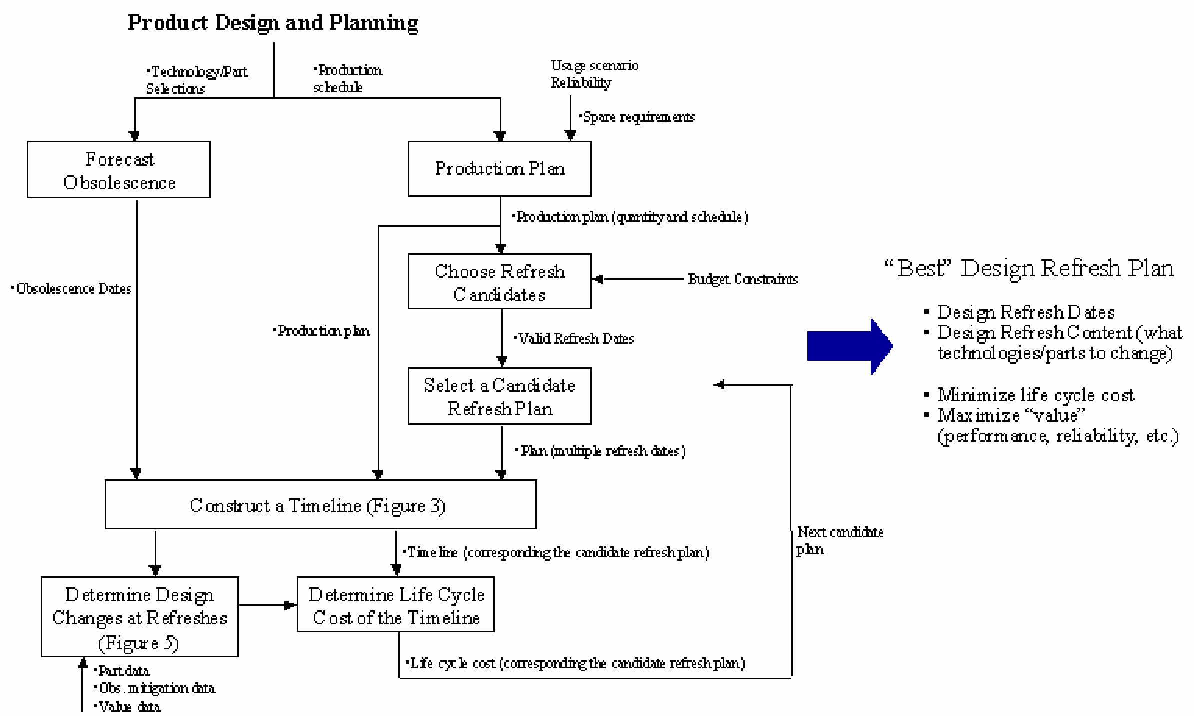


Figure 7.24 - MOCA Architecture

MOCA is implemented in JAVA, examples from the MOCA interface are shown in Figure 7.25.

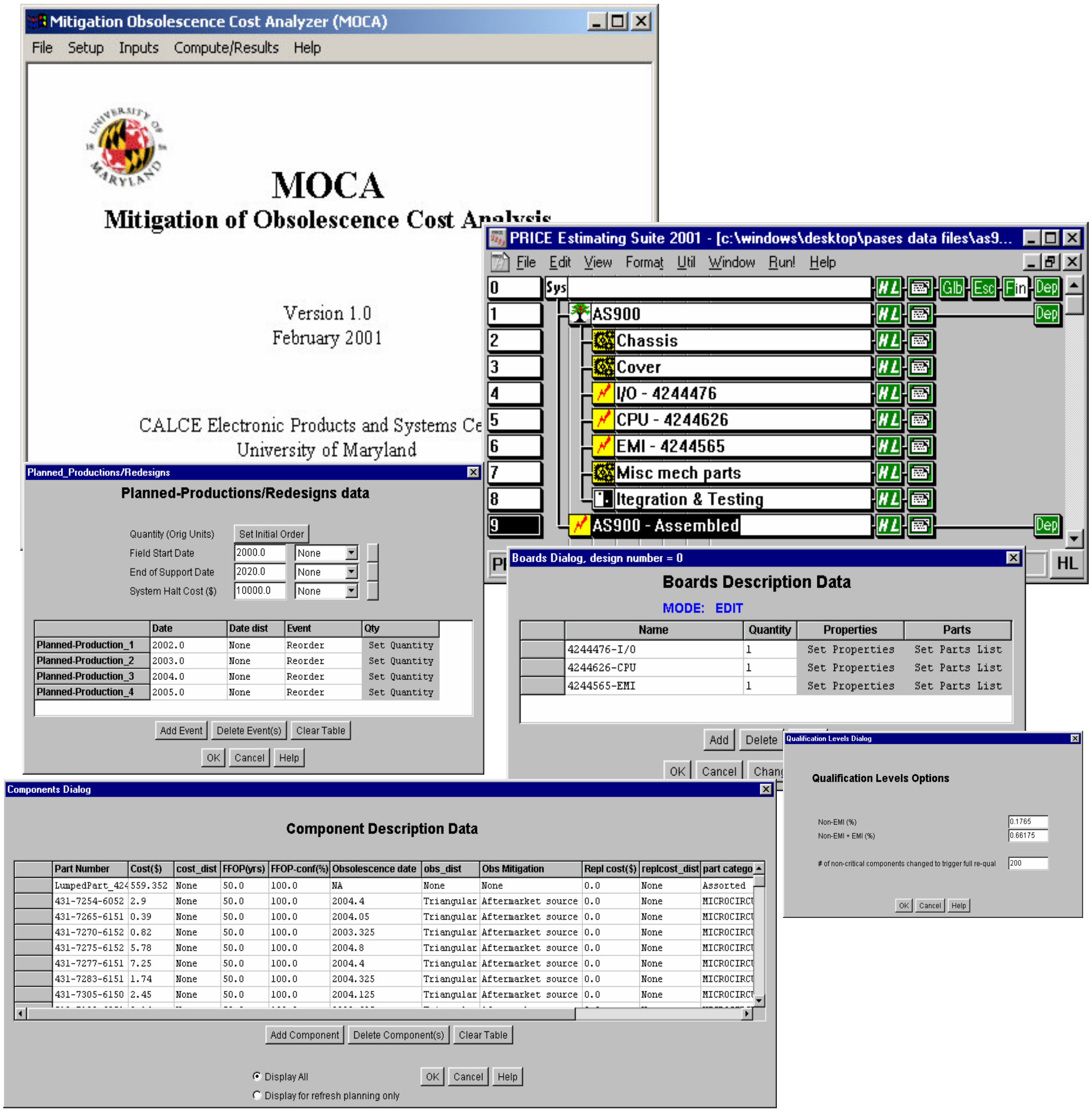


Figure 7.25 – MOCA Graphical User Interface

7.3.3.1.2 Input Data

A case study was performed for a video processor card that is part of the Arrowhead target acquisition/designation and night vision capability of the Army Apache Longbow helicopter. The application is part of the Modernized Target Acquisition Designation Sight (MTADS) program at Lockheed Martin. The portion of the system considered in this study consisted of single card containing 68 total parts (passive electronic parts and non-electronic parts were not included in this analysis) of which 42 are unique. The system has been designed for 20 years sustainment life with scheduled manufacturing taking place during the first 6 years.

7.3.3.1.3 Available Data

The following data was available for use in the pilot:

- Part prices for 38 of the 42 parts (determined via web search) – missing parts assumed zero cost
- Life codes (obsolescence risk indices) from an i2 LCM report for 20 of the parts – missing parts assumed to never become obsolete
- Production schedule (date-quantity) see Figure 7.26. The 2003 – 2004 units (39 units) are currently under contract. The 2005 – 2008 units are in negotiations as a follow on contract (665 units).

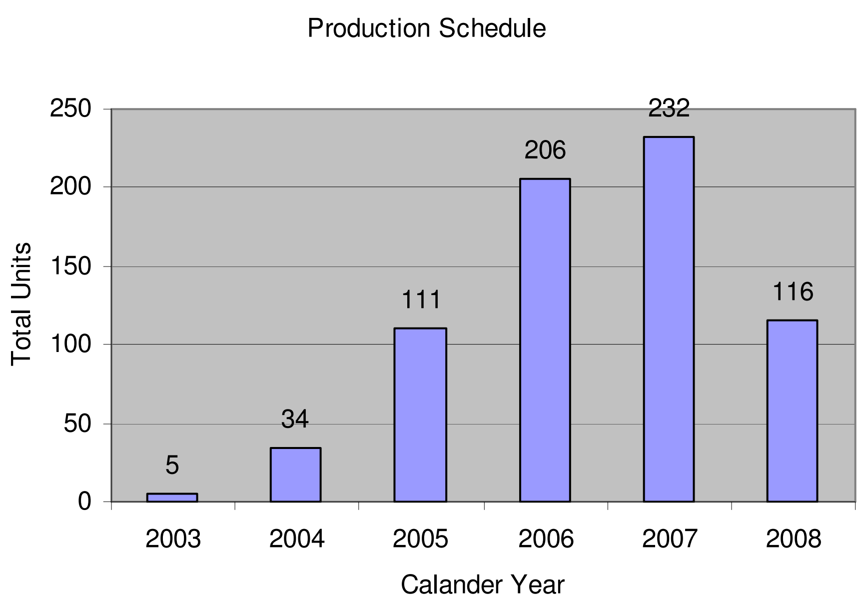


Figure 7.26 – MTADS Planned Production Schedule

7.3.3.1.4 Unavailable Data

The MTADS program was unable to supply the data listed below due to ongoing contract negotiations for the follow-on units.

- The data that was not available included:

- Qualification requirements and costs
- Specific re-engineering costs associated with board redesign due to part replacements

7.3.3.1.5 Data Assumptions

Several baseline assumptions are made due to the unavailable data:

- 20X procurement price penalty after part(s) obsolescence.
- 1-year look-ahead time.
- Non-recurring redesign costs:
  - $15K per design effected
  - $10K per board effected
  - $5K per part effected
- Re-qualification conditions:
  - $50K full re-qualification cost
  - 10 part changes qualifies a full re-qualification

7.3.4 Results

Since much of the actual data for the MTADS board was not known, some basic solution exploration was performed to identify the parameters that the solution was most sensitive to:

- The production plan (manufacturing of the units)
- What mitigation approaches are in place
- What actions are taken at the design refreshes (to what extent future obsolescence events are mitigated at each design refresh)

With this in mind the University of Maryland came up with two different solutions based on the sensitivity parameters.

7.3.4.1 Solution 1

This solution was strictly based on the production schedule provided by the MTADS program as shown in Figure 7.26. The number of units per year was combined for a total production run of 704 units.

The baseline analysis of this card indicates that a single design refresh in 2006 is optimal, and that the parts that are already obsolete by 2006 and parts that are forecasted to become obsolete within 1.5 to 2.5 years of 2006 (via i2 LCM forecasts) should be replaced at that refresh see Figure 7.27.

Analysis has indicated that the solution is most critical to uncertainties in the part obsolescence forecasts. These uncertainties are especially critical to MTADS because, the i2 LCM forecasts indicate that many parts will become obsolete between 2008 and 2009. With the assumed production schedule (that ends in 2008), if the parts don't become obsolete until 2009, then the parts don't cause problems assuming no future spare replenishments.

If the parts become obsolete earlier, they impact the scheduled builds. Because of the build schedule the uncertainties insert significant economic risk into the solution for this MTADS card. In order to quantify this risk, obsolescence dates and production dates were modeled as symmetric triangular distributions with limits of ±1 year from the point value (i.e., model the obsolescence dates as symmetric triangular distributions that extend to ±1 year of the LCM forecasted date).

The resulting lifecycle costs are bimodal distributions. The results suggest that if no units have to be built after 2008 significant cost avoidance can be realized for this application simply by carefully either holding sufficient stock of critical parts or lifetime buys.

If new manufacturing is likely after 2008, alternative design refresh and mitigation strategies are needed.

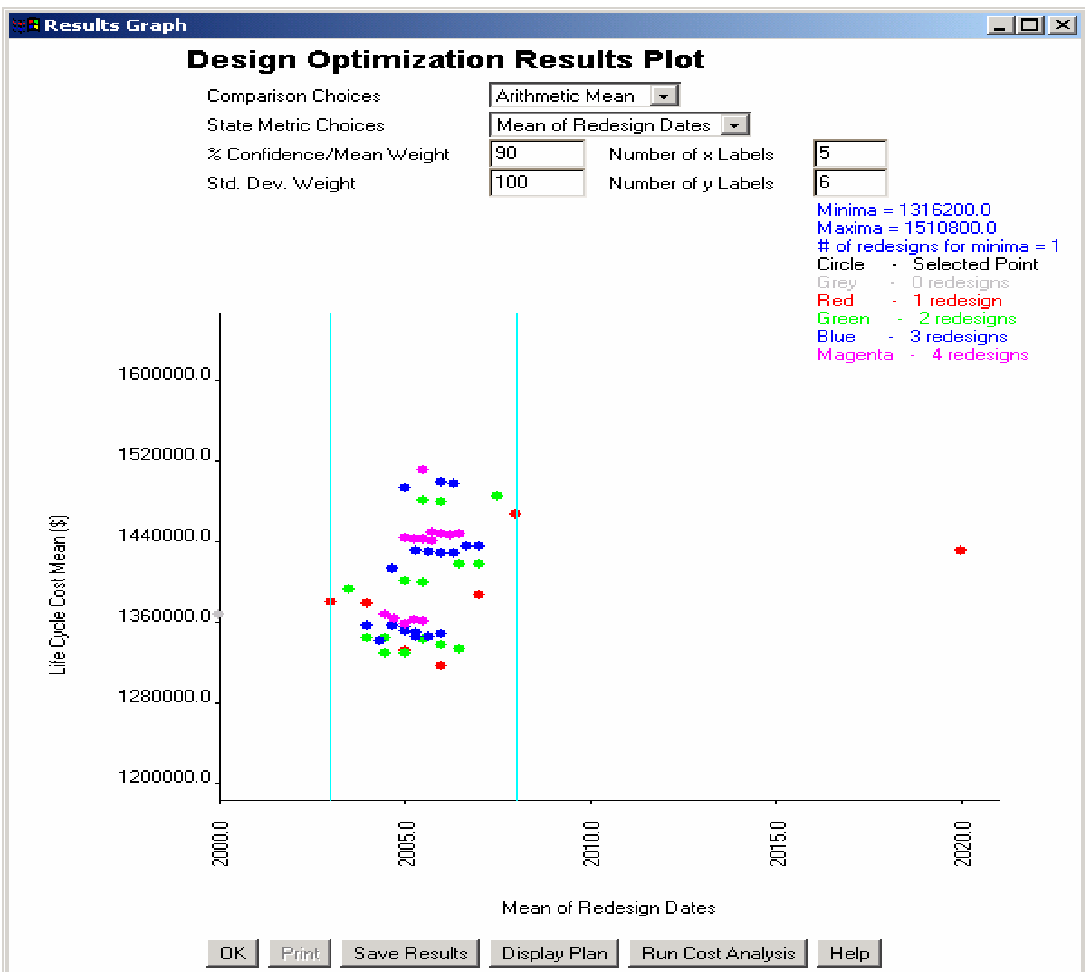


Figure 7.27 - Solution 1's MOCA Output

7.3.4.2 Solution 2

Solution 2 includes the original baseline production schedule and quantities. In addition to the baseline 50 spare units are produced in 2013. If the program decides to do a bridge or life time buy there is a large jump in the life cycle cost due to the impact of the parts going obsolete in 2008 or 2009 See Figure 7.28. The spares solution analysis of this card indicates that two refreshes one in 2006 and the other in 2013 are optimal.

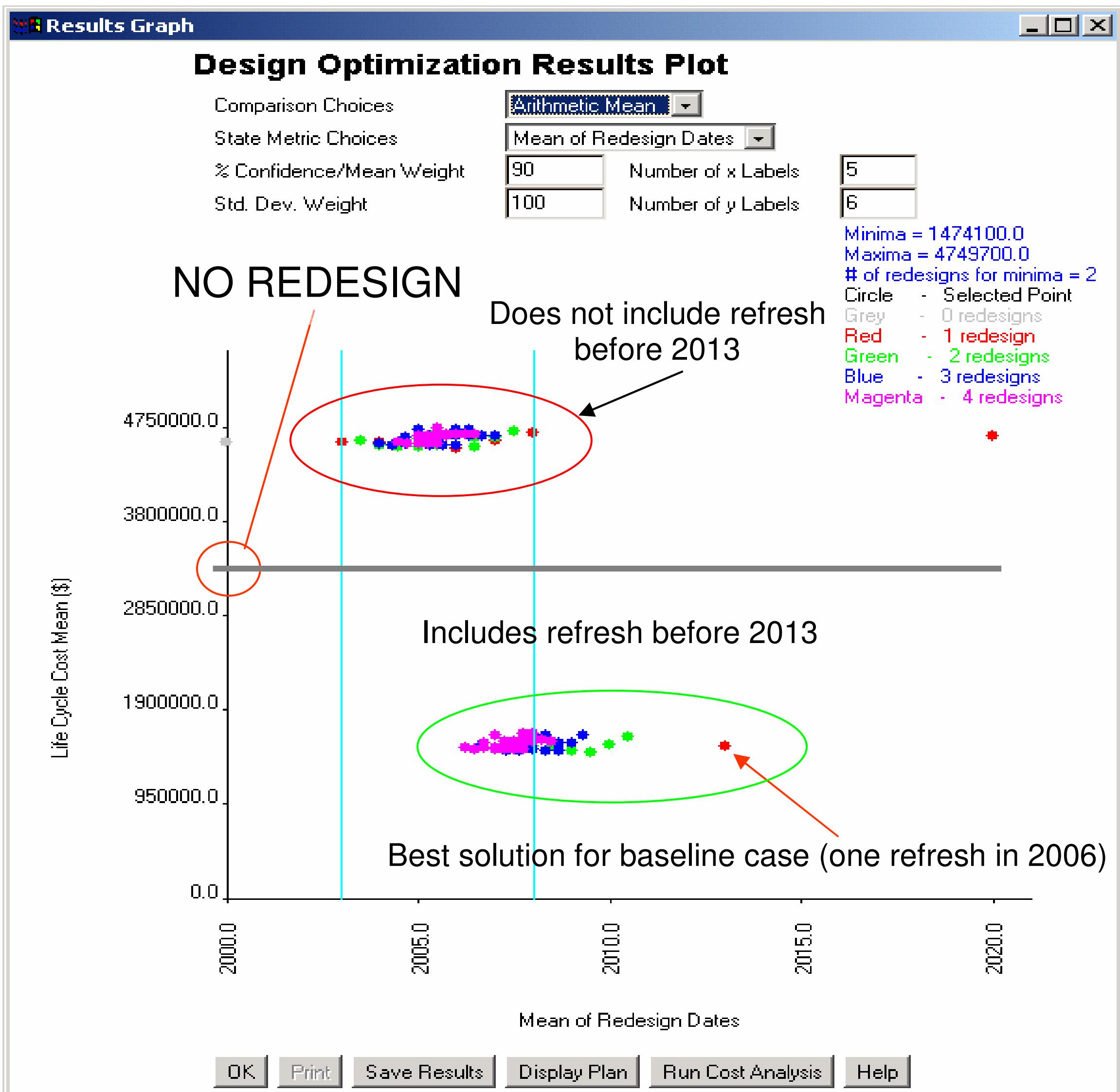


Figure 7.28 - MOCA Output - Solution 2

Figure 7.29 shows the University of Maryland has simply generalized to a procurement multiplier rather than distinguishing between different mitigation approaches. As mentioned before the multiplier is 20X original cost after part(s) has gone obsolete.

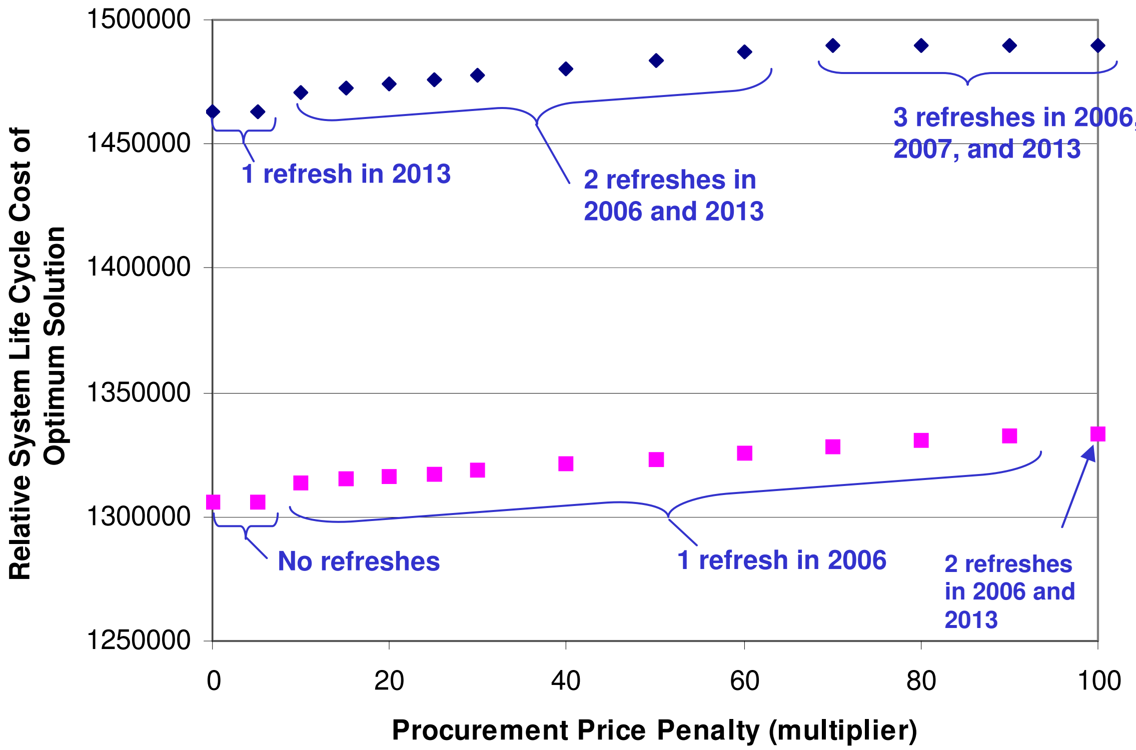


Figure 7.29 - Procurement Price Penalty

Figure 7.30 uses the procurement data plus the look-ahead time approach. The look-ahead time is: how far into the future forecasted obsolescence events are addressed at a design refresh. This helps in determining which parts should be addressed at the time of the refresh.

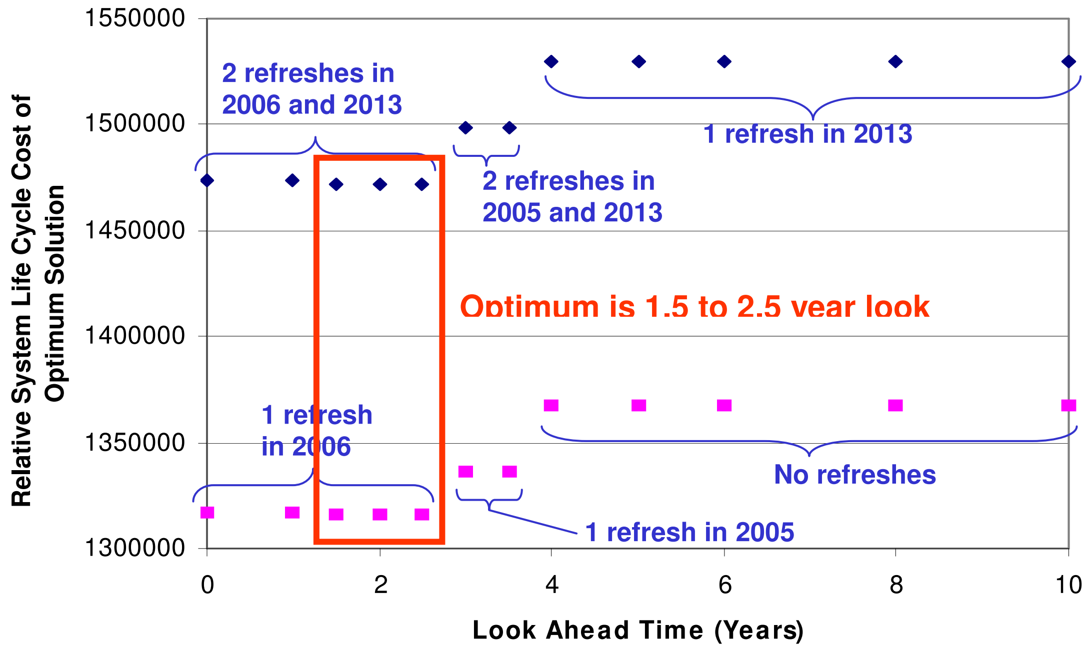


Figure 7.30 - Look Ahead Time

7.3.4.3 <u>Impact of Uncertainties</u>

Forecasting parts obsolescence dates is uncertain, whether the user is using i2 or another company. Each company writes its algorithms for predicting the date the part will go obsolete.

These uncertainties are especially critical to MTADS because, the i2 LCM tool forecasts indicate that many parts will become obsolete between 2008 and 2009. If the parts don't become obsolete until 2009, then they don't cause problems assuming no future spare replenishments. However, if the parts become obsolete before this date they will have significant impact on schedule and cost. Because of the build schedules the uncertainties insert significant economic risk in the solution for MTADS as shown in Figure 7.31.

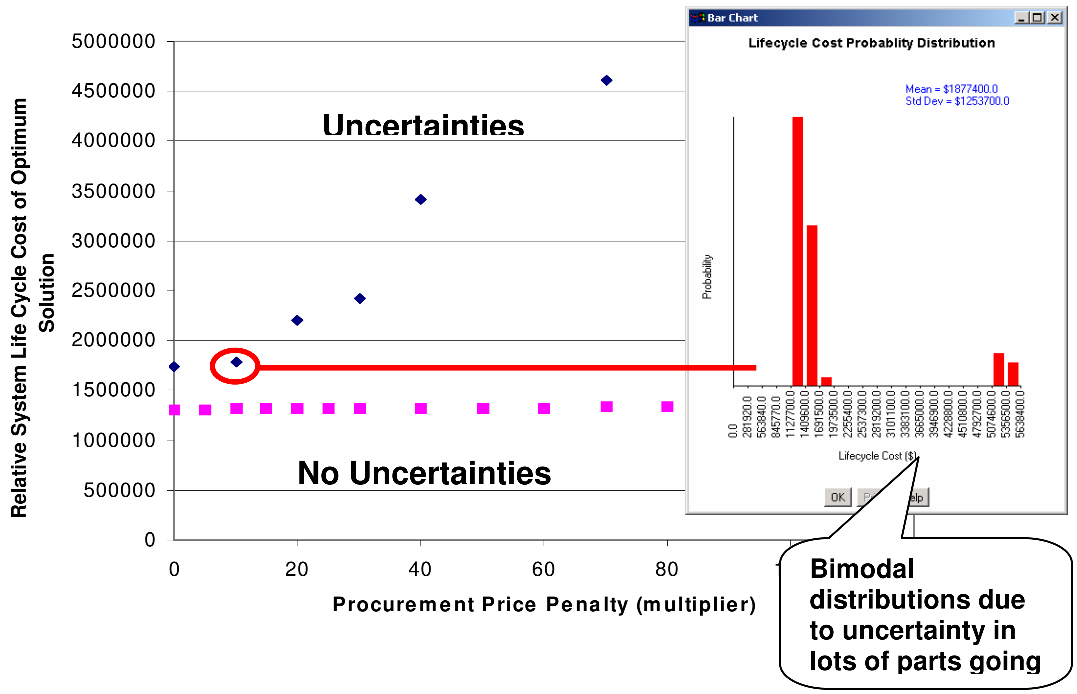


Figure 7.31 - Forecast Uncertainties

Robust optimization using look-ahead time models the obsolescence dates as

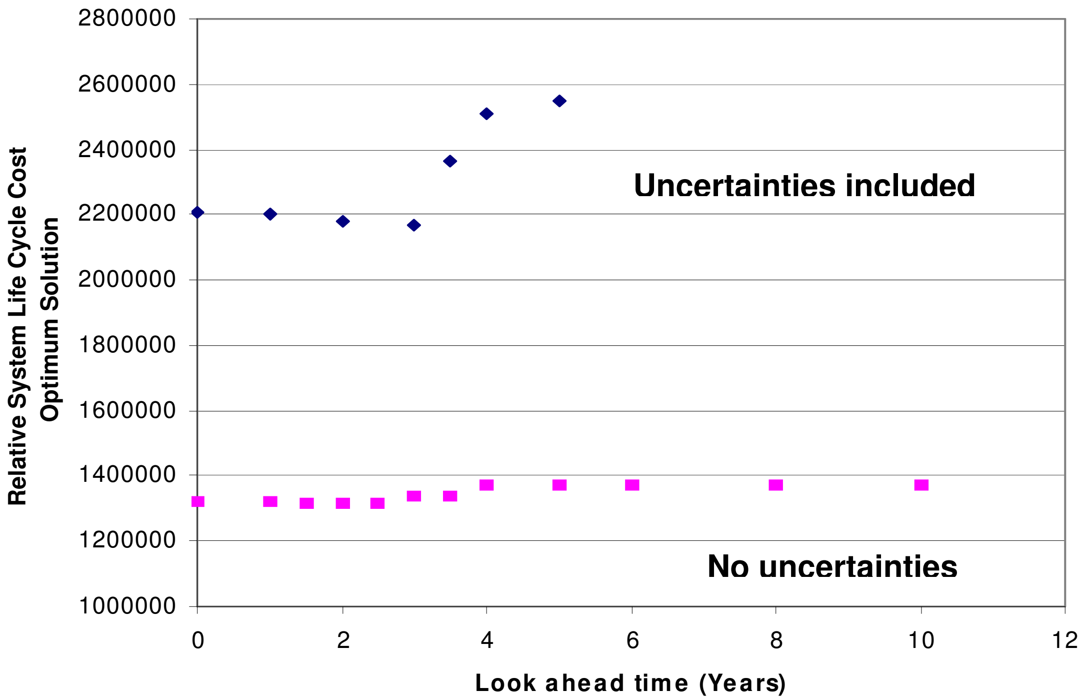


Figure 7.32 - Look Ahead Time Uncertainties

symmetric triangular distributions that extend to ± 1 year of the LCM forecasted date, see Figure 7.32.

7.3.5 MOCA Pilot Summary

The MOCA tool has potential benefits to Lockheed Martin. The primary benefit is through using the MOCA tool to develop production schedules, determine which and how many components need to be refreshed during a redesign period, and how these can maximize savings. Along with the savings the tool can help determine if a refresh is needed or if the program could use existing stock company wide, bridge buy or lifetime buy to get the production of the units completed. The tool will determine the cost associated with each of these choices allowing the program to make an educated decision and be able to modify and refine the plan as time progresses.

The user can make changes to the model and get real time answers to these changes. This allows programs to make management decisions and have the data to determine if these choices are cost effective. Plus, the program will get data on schedule impact for the choices that are made. Periodic re-running of the parts list against the LCM tool (or other tools) to get updated information on components life cycle, plus any changes made to the parts list can be incorporated into the model.

The MOCA tool would be useful during the development phase. Programs such as JASSM, which has several refreshes scheduled during the development phase could determine when the best time and how many components would be needed to maximize the cost savings.

The area of concern comes with the fact that most defense contracts are for limited quantities and have short production runs. For example: Lockheed will procure only the amount of materials needed, plus a percentage of extra parts to complete the production run and not look at additional contracts (follow-on contracts are speculation). The program won't have the resources under the current contract to refresh the hardware to eliminate obsolescence problems unless it is written into the contract or contracted and funded separately. Any refreshes that are needed will be determined during the contract period for the new buy and cost associated with the redesign will be included on a per-unit cost.

The model may show that if the program needs to refresh the hardware in the middle of the original production run it could save millions on any follow on contracts. However, the original customer wouldn't realize this cost savings and funds from that contract and they wouldn't be able to be applied to the refresh effort. This means that Lockheed would have to use overhead money or a separate customer contract to complete the effort in the hopes they receive follow-on orders to recover the cost of the redesign. Along with the redesign costs, most contracts don't allow for design changes to the hardware without performing re-qualification on the system. This would cause delays in the original production schedule to have the hardware re-qualified and be another cost that the program would have to pay along with the redesign.

Recommendation for the use of the tool would be to have the program planner and/or financial officer create and maintain the MOCA model. This person(s) has influence on program: decision, schedule, cost, and he/she reports directly to management, which allows for top-level decisions to be made based on results from the tool. Use of the tool doesn't require technical knowledge of the card(s) or system(s) to populate and maintain the model, this allows for people with little or no technical background to use the tool. By having program personnel populating and maintaining the model, the program will control the process and any changes.

The model manager will gather Inputs from the following:

- Components Engineering
- Management
- Procurement
- Others

Components Engineering can provide the parts list and life cycle data for the effected item(s). Management provides the priority list for the most important aspects of the program. For example: schedule maybe the most important aspect, because the product has to be to market by a certain date. This type of data helps prioritize the model so the tool can give a more accurate prediction base on the programs goals. Procurement can provide pricing data for the components along with other pricing issues such as: programming parts, specialized testing, etc. All of these things impact cost and schedule. Data from different groups can be added based on the programs needs. For example: transportation maybe needed to ship a missile to a firing range.

7.4 MS2 ICE / MOCA / R2T2 Evaluation Pilot

Lockheed Martin Maritime Sensor Systems (MS2), formerly Lockheed Martin Naval Electronics & Sensor Systems (LMNE&SS) - Undersea Systems, performed this study in support of the POMTT contract managed by Lockheed Martin Missiles & Fire Control - Orlando (LMM&FC-O).

The objectives of the Parts Obsolescence Management Technology Transition and Cost Methodology (POMTT-CM) pilot program were:

1) provide technical assistance and guidance to the Parts Obsolescence Management Technology (POMT) and Application of Commercially Manufactured Electronics (ACME) suppliers involved in the development of products, and to work with the program recipients under the Parts Obsolescence Management Technology Transition program (POMTT), contract number F33615-99-2-5502;
2) examine tools being developed within Lockheed Martin by employing Manassas trade-study methodology and tools against existing program data;
3) develop a demonstration plan that employs the resulting process, supported by the POMTT tools for a USAF weapon system;
4) conduct an actual pilot demonstration under a separately funded options to this SOW; and
5) validate the cost effectiveness utilizing actual business cases.

MOCA provides a Technology Forecasting and ICE provides a cost estimation capability, putting these two together would certainly have profound benefits in that a real cost estimation. Especially when performed on the cost of production program's technology refreshment. The POMTT-CM program consisted of two major tasks: POMTT development and coordination, and pilot program formulation.

This effort analyzed three (3) of the tools POMTT Electronic Parts Obsolescence Initiative (EPOI) being developed, and authored this White Paper that forwards recommendations on overlap/gaps/integration as well as improvements to them (addition of Technology Refreshment, etc). Two (2) of the three (3) tools are costing-type tools, and RADSS 2000 is a Decision analysis tool. The tools that were evaluated are listed as follows:

- ICE (Integrated Cost Estimation) tool developed by Frontier Technologies, Inc.
- MOCA (Mitigation of Obsolescence Cost Analysis) Application as a part of the PASES (Physics of Failure Approach to Sustainable Electronic Systems) program developed by Dr. Peter Sandborn at the University of Maryland

- RADSS 2000 (Resource Allocation Decision Support System) tool developed by Litton TASC (a Northrop Grumman Company)

This analysis includes identification of tool overlap, tool gaps, tool integration options, data sharing estimates, industry comparisons, (as applicable) and recommendations for future enhancements (such as Technology Forecasting and Technology Refreshment Planning). After the analysis is complete, an assessment of how these tools integrate and support a thorough CAIV analysis capability is addressed.

7.4.1 MOCA Tool Assessment

University of Maryland professor Dr. Peter Sandborn and his two graduate students (Dorethea Labogin and Arindam Goswami) hosted Mr. Butch Ardis (then the Air Force Avionics Chief Architect) and Tom Herald at College Park, MD for a technical exchange. The meeting focused on the Mitigation of Obsolescence Cost Analysis' (MOCA) capabilities and future opportunities. The initial exchange took place on 9 November 2001 and the following sections highlight the significant excerpts from that exchange and subsequent discussions.

7.4.1.1 MOCA Strengths

MOCA offers two fundamental ways of calculating cost numbers for the assessments.

- An internal set of formulas can be utilized that calculate what Dr. Sandborn refers to as "MOCA Dollars". This cost represents a portion of the "True System Total Ownership Costs" and can be used for trade study comparisons only. This cost number would not be appropriate for preparing a Life Cycle Costing Assessment for a formal Cost Proposal. However, MOCA can be consistently applied to any input bill of materials, and as such provides a trustworthy Cost as an Independent Variable (CAIV) trade study analysis.
- MOCA has the ability to leverage the Price Systems tool suite for preparing the cost analysis (Price H and Price HL). This link allows for MOCA to send data to Price, and Price provides resultant data back to MOCA.
- MOCA was originally designed to perform Production Phase Technology Assessment Decisions for the Honeywell Engine Controller. This assembly represented a "pizza box" sized electronics board with individual electronic components mounted to it. The optimizing algorithms were tailored for this activity. Therefore, MOCA is very strong and "user intuitive" with component-level analysis of an electronics board assembly.
- The MOCA application is authored in the very robust and mostly open C++ programming language. Thus, there is a ready supply of capable graduate-level students to perform evolutionary advancements and retain the strong architecture.

- The optimization engine appears to perform an iterative set of analyses to provide the user with a concise output graph that highlights the considered alternatives, and their placement on a scale of affordability (i.e. CAIV analysis).

7.4.1.2 MOCA Limitations

The following elements are delineated to describe several of the limitations of the current MOCA application. These items could also be considered as future research and potential enhancements to the application.

Failure Free Operating Periods are used (These allow for Scheduled Maintenance), as opposed to Maintenance Free Operating Periods, which the Air Force is very interested in. This limitation means that the internal MOCA cost assessment ignores maintenance requirements, and does not allow for variable maintenance strategies. This is a non-trivial limitation in that the maintenance costs may in fact be a cost driver for low reliability system elements, therefore highlighting the need for system re-designs.

Dollar information accuracy is a consideration as mentioned earlier. Dr. Sandborn refers to this calculation as "MOCA Dollars." What is in the calculation, and what is ignored? Often program TOC numbers are so huge and driven by a few cost categories tend to mask the opportunities to make improvements in the system. For example, if you allow Consumables and Manpower in the TOC number, then these two often mask acquisition and development costs over a full life cycle. MOCA does not consider these two high-cost drivers and therefore MOCA dollars represents a reasonable comparative analysis.

The Operation and Support (O&S) cost elements that are missing from Price Systems are missing in MOCA. These cost elements include Technical Documentation, and Training. In other words, MOCA does not compensate for Price cost inadequacies, and will yield a similar analysis as if a user employed Price Systems Suite directly.

MOCA does technology prediction planning using Production Schedules. These production schedules are used to "calculate the allowable times for the next Design Refresh point." The MOCA optimizing algorithm for this seems fairly robust and interesting. This does mean that MOCA is calculating the next Technology Refreshment point NOT BASED on the technologies, NOT BASED on obsolescence directly, but rather based on "Reasonableness of technology integration during a production mode". Thus a limitation, what to do in O&S phase? A more robust Technology Refreshment schema is needed here. Dr. Sandborn is thinking about leaning on "potential Price Systems improvements", however, it does not appear that this will be sufficient. Having said this, there may be very workable solution. The most desirable (from a funding stability perspective) schema for the Air Force to employ is “Scheduled Technology Refreshment Points” (which could be the considered the equivalent of a planned production schedule), and allow the MOCA tool to determine “What should be changed” at each Refreshment Point.

MOCA is focused on the Production Phase of a program. The methodology could (and should) be applied to the Development Phase and most certainly to the Operation and

Support (O&S) Phase. Currently, the MOCA application must be manipulated by the user to allow for O&S analyses. In order for the MOCA Dollar calculation to be more accurate, O&S costs must be part of the calculation for the full program life cycle versus the analysis of a particular production window. Fortunately, it seems that the structure and methodology are reasonable to adapt to this extended need.

MOCA is able to handle software only to the extent that it can be represented as a Bill of Material (BOM) line item. Dr. Sandborn plans to integrate this more directly over the next year. His vision is based on the assumption that you would have SLOC (Source Lines of Code) counts, and know the language that it was written in. This philosophy does not accommodate for "Purchased Software such as databases, operating systems, interfaces, etc." In these cases, a user would not have SLOC counts nor necessarily know the language, thus an additional mechanism must be devised and appropriately integrated. From an Air Force (or Contractor) perspective, Software is making up larger and larger percentages of the system cost. A logical way to integrate software products, development and costs is required for more accurate forward predictions.

One of the most significant limitations of MOCA currently is the inability to accommodate for "technology advantage" in the Cost Analysis. In other words, when a refreshment is planned, MOCA does a 1-for-1 replication of parts in the BOM. Thus, there is not a consideration for technology doubling providing a cost advantage to the system refreshment. MOCA has a pretty concise algorithm for deciding how much that "new part" will cost, BUT makes no provisions for hardware (or of course software) reductions over time. MOCA ignores the "Technical Capacity Growth" due to technology changes. It assumes 1-for-1 equivalency again. This leads to the notion of "System Critical Mass". This means that at some point a system can not be reduced any further (i.e. can not go below 1 processor or 1 user display as an example). There is also no accounting for merged functionality over time. This concept would represent a significant enhancement to MOCA and give it a tangible way to predict hardware (and software) reductions over the Production and O&S phases of a program.

MOCA is architected to "make electronics boards" out of "individual electronic components". It seems that ratcheting up a level or more in the system hierarchy is very feasible; however the user interface becomes non-intuitive due to the chosen nomenclature for the screens. This is easily rectified by UMD if desired by the customer.

Retrofits Planning is not considered in MOCA. MOCA is set up as a Production Environment mechanism, and the notion of retrofitting the fielded systems would have to be "dummied up as production systems". From a user interface perspective, this is not an optimal approach, and a more detailed retrofitting algorithm should be considered. Again, the solid foundation/methodology provides a reasonable way to integrate this growth capability.

The MOCA process depends on input data from TACTRAC or GIDEP alerts for initial analysis data. This may be quite sufficient for component-level parts. However, as the

BOM moves up the system parts hierarchy, other data sources will have to be considered. This is not so much a limitation as it is a usage requirement. The limitation is in the consideration that all parts must be measured on a 1 to 5 scale of maturity. While this maturity is critical to performing an assessment, a second level of consideration might include how hard the change is to implement. This element is missing from MOCA currently.

7.4.1.3 Upgrades

Dr. Sandborn received 2002 funding from AFRL Manufacturing Technologies to "link MOCA forecasting capabilities with the Cost Estimation rigor of the ICE tool from Frontier Technologies, Inc.". This exact linkage evolved over the course of 2002. The initial architecture meeting to discuss foundational interaction of ICE and MOCA took place on the 28th of May 2002 via telecom (Frontier Technologies, University of Maryland, and Lockheed Martin participating). Figure 7.33 shows the architectural interaction from the ICE perspective to MOCA.

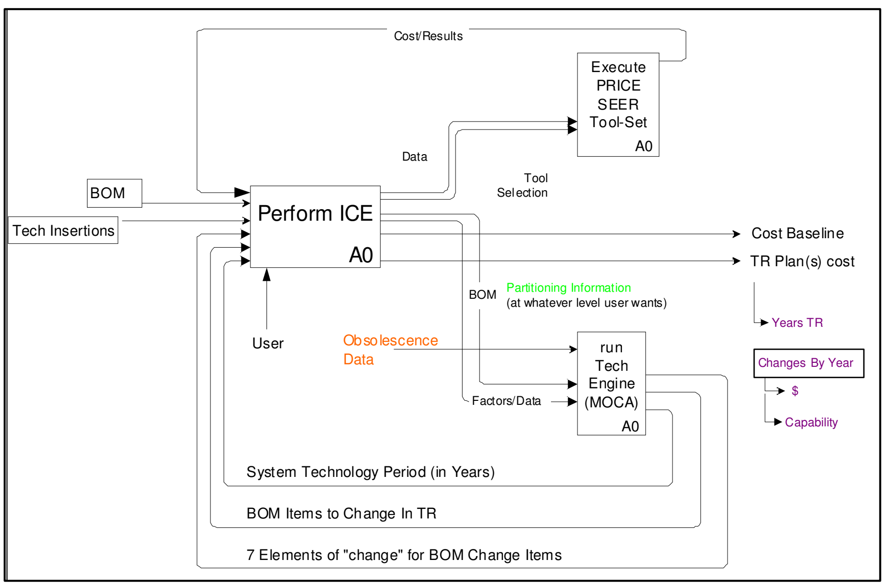


Figure 7.33 - Architectural Diagram of ICE and MOCA Linkage

7.4.2 ICE Tool Assessment

The Integrated Cost Estimation Tool (ICE) had the original goal to automate the manual processes of the Air Force Costing Estimating departments. The manual process involved retrieving data (typically from the AFTOC Database or other sources), preparing costing spreadsheets, and printing out summary/detailed information. ICE now does this in a semi-automated way for the Air Force Cost Estimator via a TurboTax-type Graphical User Interface. Thus, ICE represents a pleasant, intuitive and functional user interface shell that links the Air Force historical database (AFTOC) to common commercial and government costing tools such as Price Systems Suite (from Price Systems), SEER-SEM (and SEER-H from Galorath, Inc.) and the government CORE analysis model. The software linkages with the Price Systems suite are solidified and ready for fielding. The software linkages with SEER-SEM are already available and successfully deployed. Linkages with CORE (Cost Oriented Resource Estimating, 1994) are also in place and functioning in Air Force applications.

ICE provides an 80% costing solution, to really be used for comparative analyses. In other words, this tool is not intended for preparing final costing numbers appropriate for a Cost Proposal. Thus its primary use would be to support trade studies.

7.4.2.1 Strengths

- ICE streamlines the "necessary user data inputs" as opposed to a detailed listing of inputs that Price and SEER normally require of the user. Often this data is not easily available (particularly during a proposal or concept exploration program phase), and ICE provides a way to get a reasonable estimate of the cost in lieu of searching for much more data. In a short time and with minimal investment in data gathering, the user can get an approximately 80% accurate cost estimate. Like MOCA, this quick assessment is extremely valuable for alternative comparison trade studies.
- The user interface is quite intuitive (similar to the TurboTax commercial software in architecture). It leverages slider bars, scales, numeric inputs and other simple input mechanisms for fast mouse-controlled inputs. Additionally, there are checks performed on allowable responses precluding inappropriate data inputs driving an unusable output.
- Large amount of user flexibility in tool selection. For example, the user could use SEER-SEM for the software estimation, and could use Price-H for the hardware estimation and could also augment with user-defined Training and Technical Documentation cost estimating relationships (CER). The CERs are implemented as a percentage parametric of a summary number, but this feature could be expanded easily. This flexibility is valuable and necessary for elements that are not found in the AFTOC database such as commercial equipments.
- ICE provides the user the ability to input their own database (currently done manually, although it would be easy to provide for an import mechanism) of parts if they are not in AFTOC. Once the parts are input and the required fields are completed, ICE can run normally.
- As of the end of 2002, ICE had been deployed (via an Air Force Material Command–wide license) across the Air Force cost estimating personnel. This consistency will also have a powerful impact on trade studies being "shared" among the costing groups.

7.4.2.2 Limitations

- Linkage only to Air Force Databases such as AFTOC. Linking with VAMOSC (the Navy historical database) or others will require specific programming, and possible changes to the user interface screens as a result of these differences. This is a reasonable investment should there be a desire to use ICE in other services. CAUTION: There are many “assumptions” employed in ICE to free the user from minutia. While this is necessary, it is also a risk when moving to non-Air Force applications. These “assumptions” would need to be re-validated. As these assumptions are proprietary to ICE, a relationship would be required.
- Leverages (and actually depends on) using historical data only. There is flexibility provisions for the user to input a Cost Estimating Relationship when historical data is not available for a part, however these are time consuming and burdensome to the user to have to do this.
- ICE is Product-Centric. It is not possible to perform analysis on “technologies” versus parts. There may be a reasonably simple way to add this enhancement.
- Although ICE provides a very intuitive user interface for nominal data input and execution. It is necessary to have an “intelligent user” for understanding what is being done behind the scene by Price, or SEER or CORE. Training is not an option with ICE it is mandatory to gain expert understanding to ensure that it is not misused.

7.4.2.3 ICE Tool Summary

ICE is a powerful trade study tool. It can be used for comparing various contractor bids, or as a contractor to analyze various architectural alternatives for optimal affordability. ICE certainly supports the CAIV requirements on many Requests for Quote. However, the most significant limitations to consider are non-Air Force applications, and commercial product applications. These offer significant challenge for the user, since the database linkages are not available.

7.4.3 RADSS 2000 Tool Assessment

A meeting was held at the Northrop Grumman Information Technology (Litton/TASC) office in Dayton, OH, with Mr. Guy Engler who provided extensive insight into this tool, its best uses, and where it does not have substantive application. The exchange was professional and open.

In the view of Northrop Grumman IT, RADSS 2000 is primarily used for large-scale decision analysis such as the following example technical situation:

A modernization is being planned for C-5 aircraft. There are upwards of 1000 “good ideas” to be implemented for the modernization. However, there is a limited budget within which to maximize the benefits.

Therefore, the primary usage for RADSS 2000 is to determine the "Best Value Combination" of alternatives from a very large list of alternatives. If for example, there were only 10 alternatives, there are much simpler (and less costly) decision analysis tools (Such as Expert Choice, the AHP tool, Keopner-Tragoe spreadsheet analysis, etc.)

7.4.3.1 RADSS 2000 Strengths

- A mechanism for determining "Must Haves," "Wants" and "Wish List" requirement items. In the C-5 example, this means which of the 1000 good ideas, which ones must be accomplished due to obsolescence or tactical changes (Must Haves), which ones offer new and desirable functionality (Wants) and which of the projected ideas are nice to have, but will not harm the required mission if they are not implemented (Wish List).
- RADSS 2000 performs a sophisticated Optimization Algorithm to analyze the "combinations of good ideas" that lead to a Best Value program modernization benefit for the available funding. It takes into account the categorization of the items as described in 1 above.
- The supreme capability of RADSS 2000 is in performing extensive real-time "What-if scenario analysis". What if the program had more money? What if the program ignored certain elements? What if the schedule was different? Are there political factors to consider?
- The output graphics and tables are wonderful tools for understanding the problem set, as well as honing in on an acceptable solution. However, reading and understanding the output is non-trivial.

7.4.3.2 RADSS 2000 Limitations

- How are the weightings of decision factors determined? A mechanism is required outside of RADSS 2000. Such as with Expert Choice, and then the user inputs them into RADSS 2000. Once the information has been developed to implement Expert Choice (or a Decision equivalent), then only a large-scale decision would warrant moving the information to RADSS 2000.
- There is an immense level of Training required in order to be an acceptable user. This training must then be followed up with repetitive usage across the year, otherwise the skills and knowledge will wane and RADSS 2000 will be unusable. This application is essentially a huge spreadsheet with detailed mathematical algorithms applied against the data in order to provide the outputs.

7.4.3.3 RADSS 2000 Recommendations

This study recommends that in the very few circumstances that Lockheed Martin needs to make a C5-like decision, that LM hire Guy Engler and his Northrop Grumman (TASC) team to support the analysis. This recommendation is due to the fact that RADSS 2000 is quite expensive and demands a very skilled and intelligent user. The following reasons support this recommendation.

- The process that the tool uses is rather complex and not immediately intuitive.
- The optimization portion is the true intellectual property of NG (TASC), and also demands an intelligent user to set things up correctly, and to play the what-if scenario game.
- The tool cost is very expensive, but having someone that is fully trained and practiced on this tool is also a significant investment. The return on this tool and training investment is only valuable if Lockheed Martin (or other contractors) have enough analyses to perform over the course of a year. As a whole corporation, LM might be able to put together enough projects to warrant the investment, but certainly as an individual LM site, it would not.
- RADSS 2000 can be used to conquer smaller decision analysis studies. However this would be the equivalent of pounding in a finishing nail with a 6-pound sledge hammer. It is overkill and risks losing the decision focus in the complexity of setting up the model. Therefore how we choose to implement RADSS 2000 is a serious decision. It is recommended that the talent of Guy Engler and his team be leveraged for the few specific analyses LM might have.

7.4.4 Rapid Response Technology Trade (R2T2) Tool Assessment

There are a variety of commercially available tools that are all focused on Pre-Planned Product Improvement (P3I). In other words, once obsolescence concerns begin to occur within a program, and it becomes obvious that "change will be necessary", the questions then become: What refreshments should be made? What additional functionality can be added? And what funding is available to make changes with? These are important steps in keeping a program viable; however, as it turns out these are all after the fact reactive analysis. In this case, system obsolescence has already started and then an assessment is made for what else might be close to obsolescence. The focus of R2T2 is on early forward predictions using technologies and their assessments for providing those forward predictions. Then the question of "What to Change?" can be addressed.

R2T2 is intended to provide, as the name indicates, a Rapid Response engineering aid in performing trade studies with very limited information. This need often exists in the Proposal, Concept Exploration and Concept Advanced Development stages of a program. In these stages very little data is available, and the challenge is to use this data and make the best strategic and planning decisions possible. Figure 7.36 shows the top-level Enhanced Function Flow Block Diagram including Inputs on the Left, Mechanisms on the Bottom, Controls on the Top and Outputs on the Right. Of particular note are the two outputs entitled Technology Refreshment Strategy and Technology Refreshment Plan. These are developed using the Program Operational Life Input (be it 30, 40 or 50 years). The focus is on developing a full life cycle plan, and not just a 5-year or 10-year forward vision, which is often typical with program plans today. This myopic view of a program does not allow for technology management, but rather encourages reactive problem resolution.

The Technology Refreshment Strategy output is defined in terms of months, and represents the frequency which the system should receive Technology Refreshment attention. R2T2 allows the user to select multiple Technology Strategy alternatives, each of which is analyzed for the full life cycle thereby determining the optimally affordable strategic solution.

The Technology Refreshment Plan output is a matrix with the full Bill Of Materials (BOM) on the y-axis of the matrix and the full Program Operational Life along the x-axis. Each block in the matrix contains the determination of whether or not a BOM line item will change in a Technology Refreshment year and if it is to change then what level of change will occur (based on Table 7.1 recommendations). This represents a two-dimensional complexity of change; first is the need to change based on the technologies that appear in the product (sub-system, or system) and the second element is that once change is determined to be necessary, how big will the change need to be? Is the change Form, Fit, Function and Interface (F3I) compatible? These factors drive two results, cost and performance (measured in the form of capacity potential).

Table 7.1 - Proposed Levels of Technology Changes

TECHNOLOGY REFRESHMENT/INSERTION LEVEL
Level 1: Simple component replacement that is completely Form, Fit, Function & Interface (F^3I) compatible where minor, if any, re-testing is required. Done for DMS reasons or by Supplier decision for improved reliability, cost, etc. For hardware, this means the two final assemblies are interchangeable.
Level 2: Part change involving not only a change to components, but also firmware, or board changes. Still is completely F^3I compatible, and will require some re-testing.
Level 3: Major Part Change for Refreshment and/or for Insertion. This re-design probably affects hardware Form, Fit, and likely Function (more capacity and/or added capability). Probably a shrinking of size and cost. The Interface standard, however, is held constant. Software/Firmware are likely affected (new drivers, process application re-allocation, etc.) Open System Interface Standards are still valid.
Level 4: A Technology Insertion. Similar to Level 3 with addition of OSA Interface Standards changes also. In other words, the OSA Standard changes (that the program has chosen and implemented); thus the design must adapt to that change, or migrate to a new/different standard altogether

From the Technology Refreshment Plan, R2T2 is able to calculate a course Total Ownership Cost used for the comparison to other alternatives. This comparison determines optimal affordability.

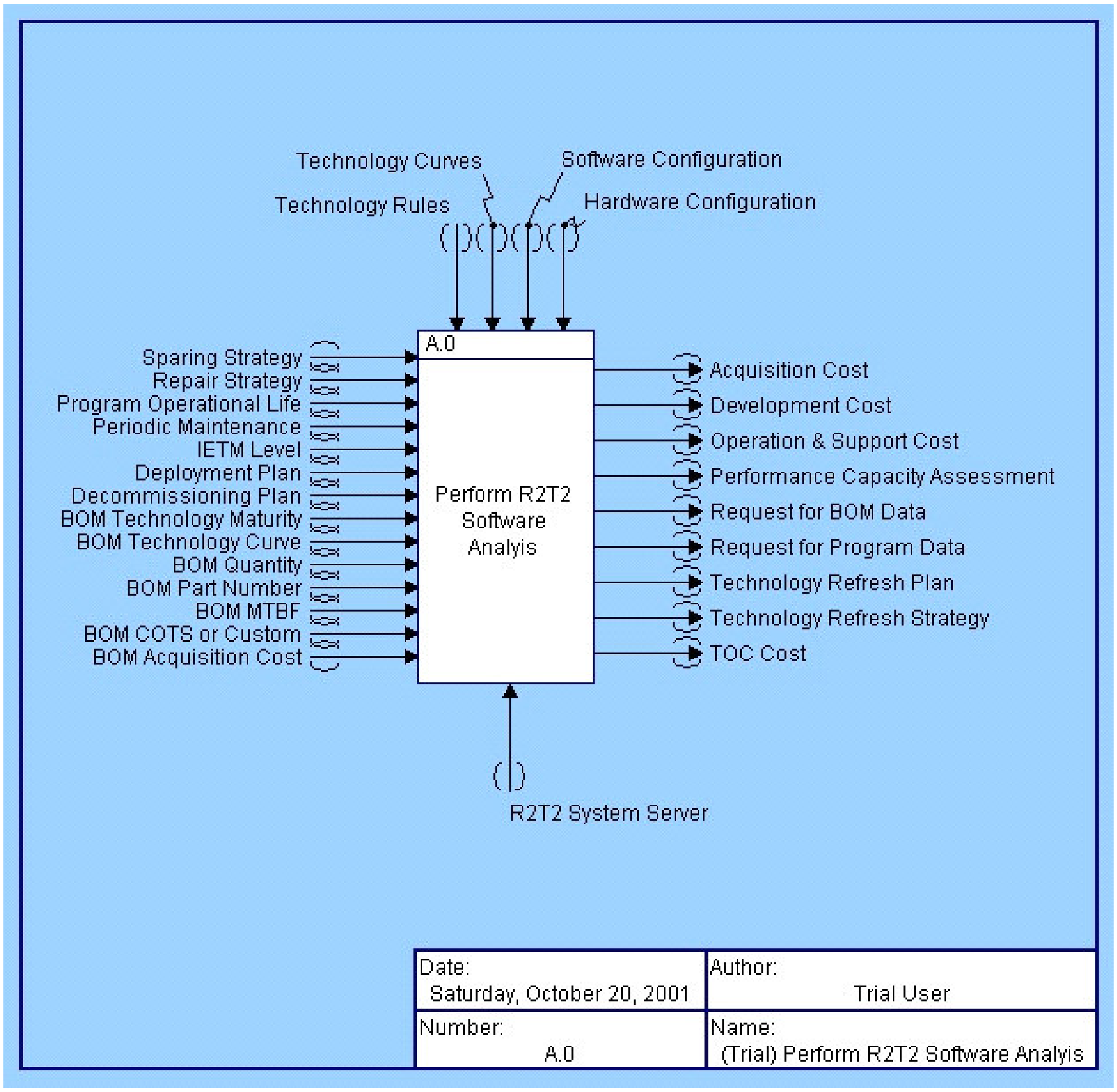
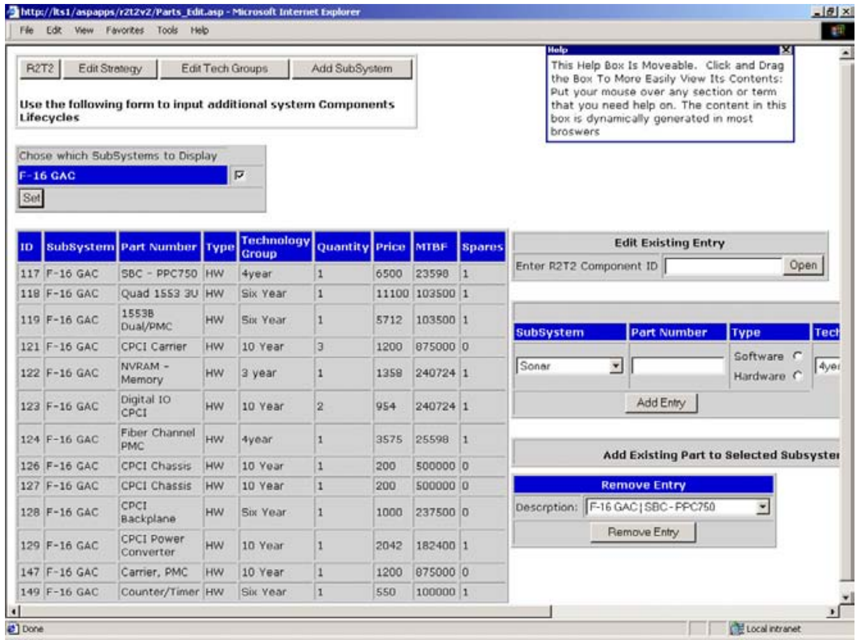


Figure 7.34 - R2T2 Top-level Inputs and Outputs

7.4.4.1 <u>R2T2 Input Data</u>

Once the required information has been obtained for each BOM line item, and program-selected Technology Strategy Alternatives have been determined then the analysis can be performed. The following two figures, Figure 7.35 and Figure 7.36 respectively, represent this information for an example from F-16 GAC.



ID	SubSystem	Part Number	Type	Technology Group	Quantity	Price	MTBF	Spares
117	F-16 GAC	SBC - PPC750	HW	4year	1	6500	23598	1
118	F-16 GAC	Quad 1553 3U	HW	Six Year	1	11100	103500	1
119	F-16 GAC	1553B Dual/PMC	HW	Six Year	1	5712	103500	1
121	F-16 GAC	CPCI Carrier	HW	10 Year	3	1200	875000	0
122	F-16 GAC	NVRAM - Memory	HW	3 year	1	1358	240724	1
123	F-16 GAC	Digital IO CPCI	HW	10 Year	2	954	240724	1
124	F-16 GAC	Fiber Channel PMC	HW	4year	1	3575	25598	1
126	F-16 GAC	CPCI Chassis	HW	10 Year	1	200	500000	0
127	F-16 GAC	CPCI Chassis	HW	10 Year	1	200	500000	0
128	F-16 GAC	CPCI Backplane	HW	Six Year	1	1000	237500	0
129	F-16 GAC	CPCI Power Converter	HW	10 Year	1	2042	182400	1
147	F-16 GAC	Carrier, PMC	HW	10 Year	1	1200	875000	0
149	F-16 GAC	Counter/Timer	HW	Six Year	1	550	100000	1

Figure 7.35 - R2T2 F-16 GAC BOM and Technology Inputs

The technologies used in this F-16 example system are split between “Fast-paced changing products” such as the Single Board Computer and the NVRAM Memory and the “Very Slow-paced changing products” such as Power Supplies, Back Panel, and Discrete Input/Output circuitry.

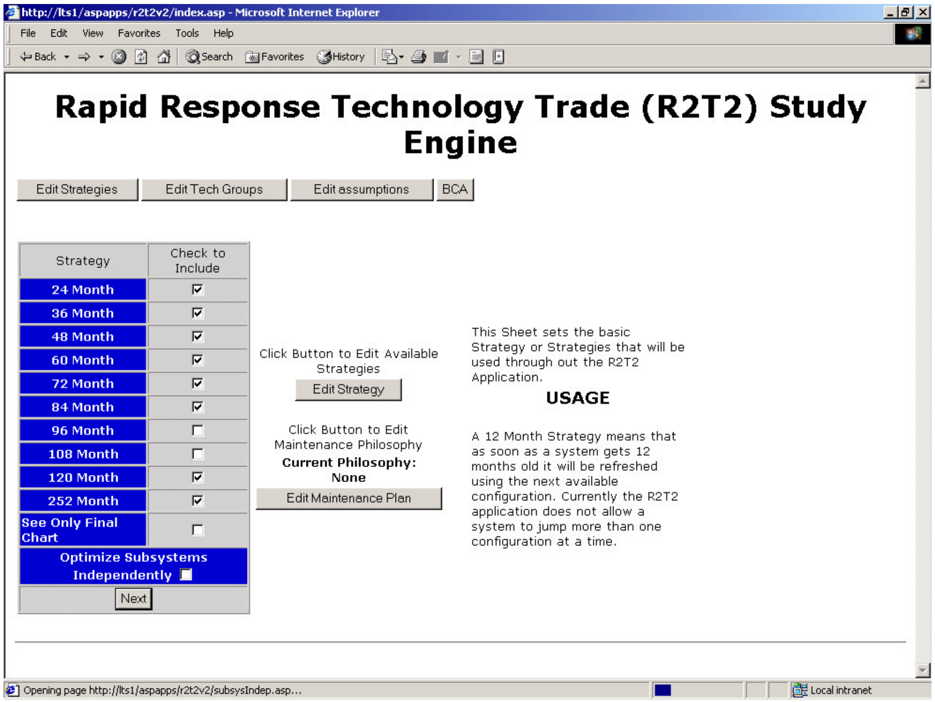


Figure 7.36 - Technology Refreshment Strategy Alternatives Used

R2T2 allows for Technology Refreshment Alternatives to be determined on any number of months. Typically they are analyzed using 1-year Technology Refreshment Frequency through a 10-year Technology Refreshment Frequency increment. Affordability is used as the optimizing variable (full life cycle affordability) and a final output graph shows the results for each of the independent iterative runs (from 1-year to 10-year).

The optimizing variable used for the selection of which Technology Refreshment Alternative proved to be the best is shown for the F-16 example in Figure 7.37.

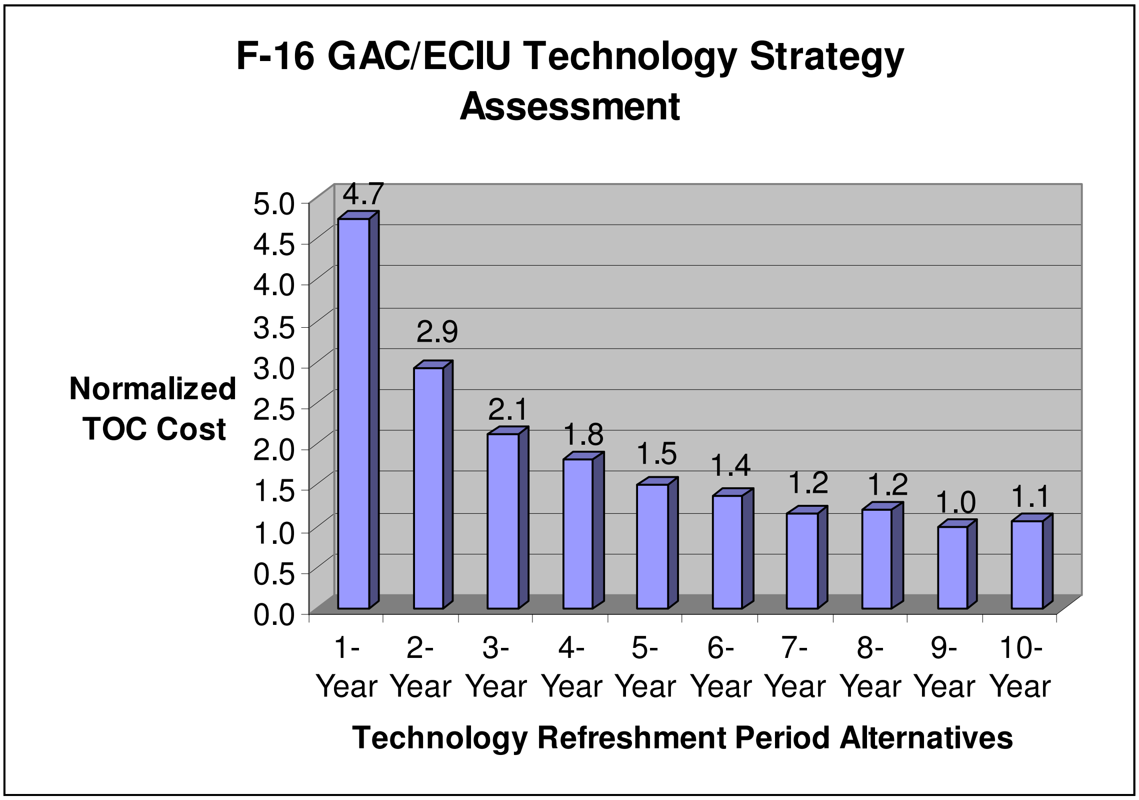


Figure 7.37 - F-16 GAC Technology Strategy Analysis

7.4.4.2 <u>Strengths</u>

- Ability to analyze a Bill of Materials or a listing of Technologies to determine the programmatic change frequency and affordability of the decision alternatives. R2T2 is based on "Technology Monitoring" versus part number monitoring. This gives R2T2 an advantage to use this to more easily project across a life cycle for total ownership costing.
- Analysis of operational capacity over the system evolutionary life cycle in addition to cost. This means as processing speeds and memory densities double, the tool takes this into account and uses this capacity to offer greater system affordability.
- R2T2 allows for the "reduction" of solution based on the performance capacity down to the critical mass of the physical architectural solution.
- Applicability to Software is again technology based versus sole dependency on Source Lines of Code estimates (which are very undependable for commercial product estimates).

- R2T2 is effectively implemented at ANY level of the system hierarchy. The top-level system can be analyzed, and then each of the sub-systems can be analyzed, all the way down the tree to the Lowest Replaceable Unit, or to the component level.

7.4.4.3 Limitations

- R2T2 is still near the end of the development stage; however, validation has been on only 4 projects to date. More validation is necessary.
- Targeted-User cost element definition would enhance the reliability of the results.
- Integration with Price is underway in the forth quarter of 2002. Validation to occur in 2003. Currently R2T2 is similar to MOCA in that "R2T2 Dollars" are calculated and they represent only a subset of the true and actual Total Ownership Costs.

7.4.5 MS2 ICE/MOCA/RADSS//R2T2 Evaluation Pilot Summary

PASES and MOCA both use Price Systems as its engine, but MOCA does this in a component-oriented approach. It does not address internally developed software or its relationship to system changes. MOCA uses a TACTRAC or similar obsolescence forecasting database, input along with production schedules to determine tech refresh estimation. MOCA also uses a unit of measure called "MOCA Dollars" that have to be converted to real dollars in order for any estimation to be valid. However, linking to Price may provide this info.

MOCA assumes no failures, regular maintenance is performed during operating periods, and that no Operations and Support (O&S) data is included. It also assumes a 1-to-1 replacement scenario and does not take into account improvements from technology and system capability improvements. It is not designed to handle system retrofits.

ICE, although designed to handle the Air Force Total Ownership Cost (AFTOC) database, is too myopic and constrained by its current design. ICE only uses AFTOC data and does not determine whether it is good or bad. It does contain code-level links to Price systems products. It also allows for manual input of outside costs such as training, refresh, etc. but cannot link to outside sources without specifically-defined coded interfaces. ICE also only has historical data but does not help the COTS issue, and is primarily parts oriented. It does not address cost issues related to technologies.

7.4.6 RADSS for PCB Manufacturing Pilot

Dallas undertook its Production Resource Allocation Decision Automation (PRADA) Pilot to explore the utility of Northrop-Grumman Information Technology's Resource Allocation Decision Support System (RADSS) 2000 decision support tool. In the PRADA pilot, RADSS was applied to the allocation of resources in

Missiles and Fire Control – Dallas' advanced printed circuit board (PCB) manufacturing process.

The production of complex circuit boards requires numerous process steps. Production personnel must rapidly decide how to handle changes in job priority, quality control issues, out sourcing, maintenance schedules, etc. to optimize the productivity and cost effectiveness of their limited resources while meeting production and tool utilization requirements. This is a complex task with many overlapping requirements and cost benefit trades. The manual handling of this decision process is time consuming and may result in unanticipated conflicts and production inefficiencies.

A preliminary assessment of the utility of RADSS was performed and a business case was developed to transition this approach to PCB production decisions and (potentially) other appropriate manufacturing processes.

The RADSS tool requires user to input data and set up rules and constraints on the decisions. Resources data was gathered (# of machines, machine hours, # of operators, operator hours) for four different PCB manufacturing processes and imported into the RADSS database. Next, a decision tree, problem sets, and scenarios were developed inside RADSS tool to analyze and make daily decisions on the processes. This is explained in greater detail in the following sections.

7.4.6.1 <u>Background</u>

RADSS was developed by the former The Analytical Sciences Corporation (TASC) in Fairborn, OH which was renamed to Northrop Grumman Information Technology (NGIT) after Litton Industries acquired TASC and Litton was acquired by Northrop-Grumman. NGIT developed RADSS in partnership with a major electronics manufacturer to help that organization with critical product investment decisions.

The tool applies relational database technology (Microsoft Access), linear programming, Boolean logic and an Analytical Hierarchal Process (AHP) to the structured decision process to optimize the cost-benefit ratio during the selection of alternatives under the constraints on relevant resources.

7.4.6.2 <u>Approach</u>

A structured decision process was developed at M&FC-D in order to organize decision rules, logical relationships, and priorities for representative PCB manufacturing processes in RADSS tool. Before problem sets could be entered and a decision model created, the RADSS database had to be setup. Classifications (classification schemes, classification table, and classification options and Create Cost/Resource Attributes (Groups and Table) were developed in an Access '97 database call R2K.mdb. Once this database was setup, data was imported using RADSS' import utility. Resources were collected required for four different PCB manufacturing processes. Specific data points collected included:

- Machines required
- Operators required to setup and run machines

- Resources required to operator machine
- Machine time required
- Operator time required
- Number of operators required for miscellaneous work

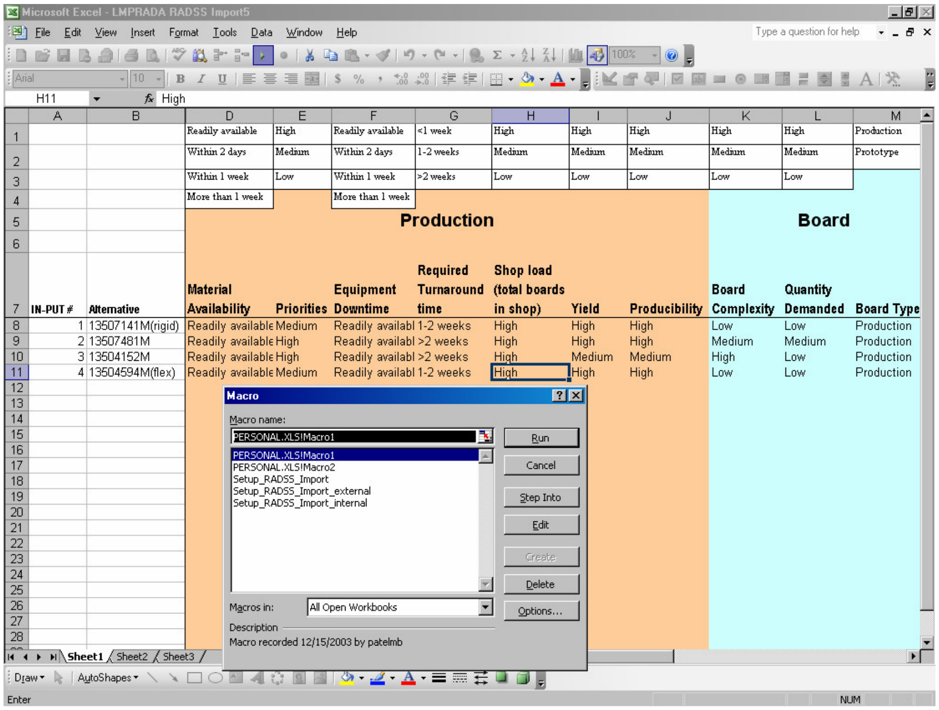


Figure 7.38 – Data Input File

In this project, an internal and an external decision tree was created to model the decision process of whether to manufacture PCB boards in house or to outsource them. PCB process types were used as alternatives and each alternative would have resources as attributes. For example, PCB Process A will have Machine A, Machine B, and Operator C and E as resources. In addition, each of the alternatives was scored based on the decision model selected. A scenario was also created for everyday used called “Daily Internal Decision” which included all four alternatives (PCB processes). This was run to apply many different constraints on the resources (machines and operator hours) to get realistic benefit/cost ratio.

Next, NGIT's five step decision process was followed to create decision models and scenarios for the PCB manufacturing process. The first step is to create models for each type of decision to be made in the entire decision process. This includes both the criteria weighting and standards. A portion of the PRADA decision model is shown in Figure 7.39.

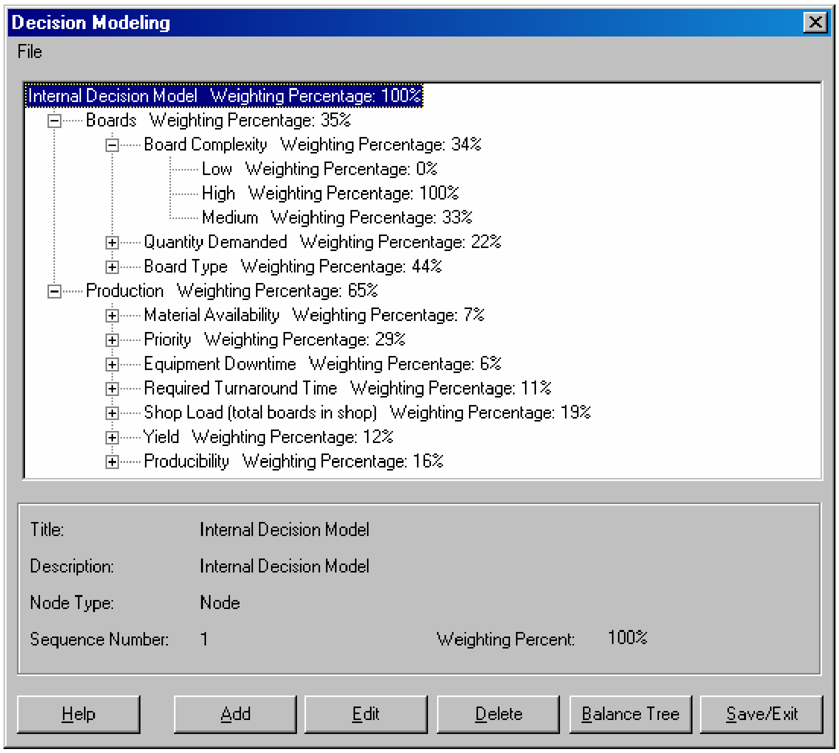


Figure 7.39 – Problem Decision Tree

The next step is to create a complete problem set by assigning a decision tree to the problem and assigning cost attributes that will be used as part of the decision optimization. This is illustrated in Figure 7.40. It can be seen that the desired decision to be optimized (Maximize Throughput) consists of 4 branches: Maximize Throughput, Daily Decision, Internal Selections Only, and Daily Decision Resources Selection. Each of these would have at least one associated Scenario (In the lower section).

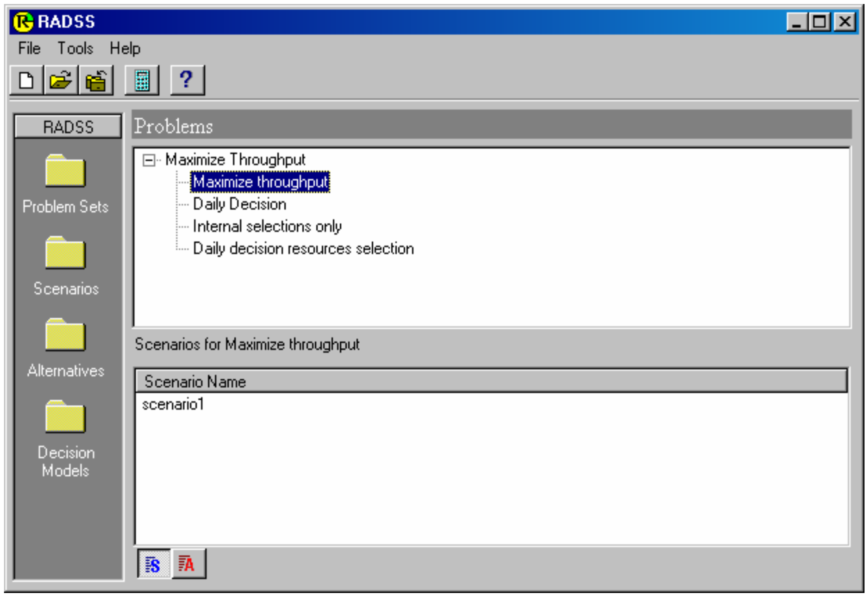


Figure 7.40 – Problem Set

The third step is to assign the values to each problem by assigning each one a decision tree model and assigning them to a problem set (Figure 7.41).

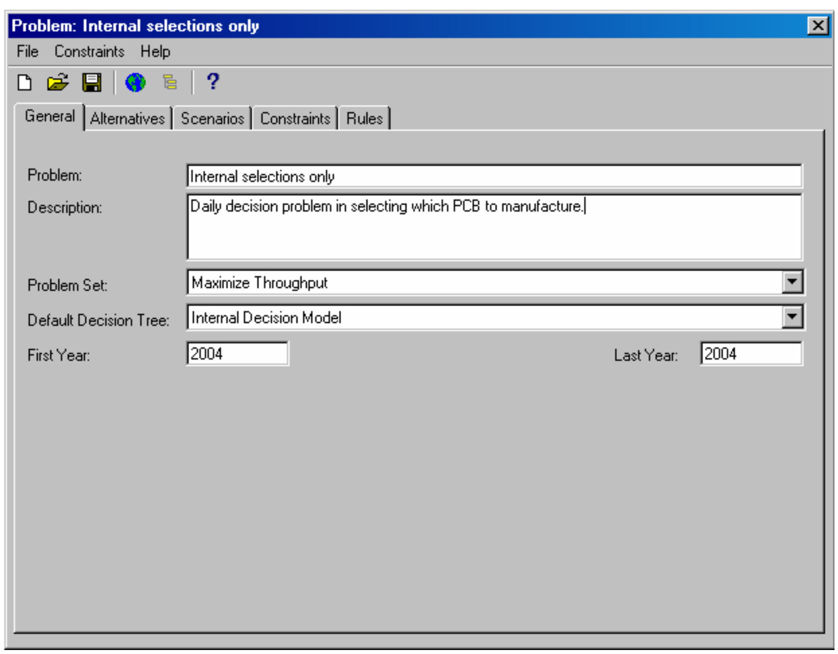


Figure 7.41 – Sample Problem

The next step in the decision model creation process was to create a list of alternatives Each one had to be assigned to a problem and decision tree. Classification data was input, and cost and resource data were added to 3 Attribute groups Equipment Hours (Time to Manufacture), Optimum Cost, and People (Manpower). A score for each alternative was also established for each based on the decision criteria and decision model selected

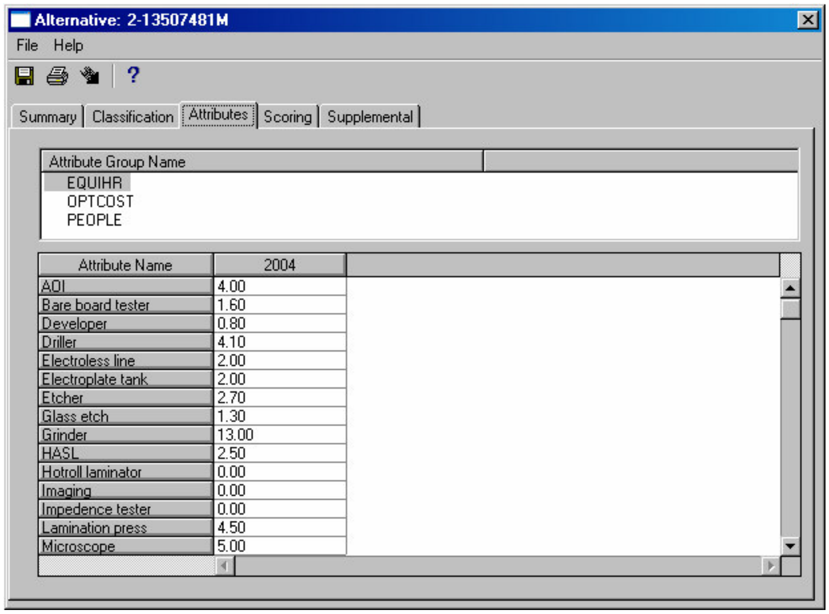


Figure 7.42 – Alternative Attributes

The final step in the model development process was to create scenarios by assigning to the decision a problem/problem set, a decision tree, telling the software to optimize on the AHP score. The user also had to identify a time period for the optimization and identify the alternatives that were to be included in each scenario. Finally, the cost and resource data constraints were input and a set of Boolean rules were established. The rules prevented the occurrence of unallowable or otherwise invalid decisions from taking place.

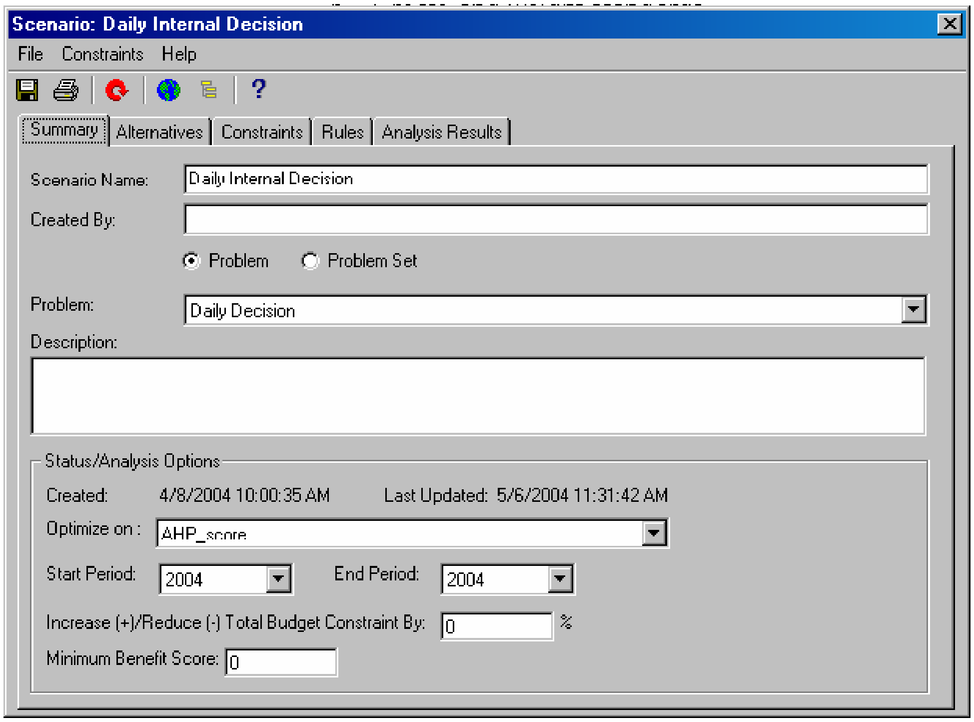


Figure 7.43 – Scenario Summary

7.4.6.3 <u>Pilot Results</u>

The decision model was run using the established scenario and the results were examined to provide a sanity check and evaluate the optimum solution. This is illustrated in Figure 7.44 under the combined Benefit/Cost column.

RADSS generates a Benefit/Cost ratio for each of the alternatives selected for particular problem in the scenario. Along with ratio, the result screen displays whether the alternative was selected (True), or not selected (False), depending on the constraints and rules that were applied. As can be seen, the optimum decision provides the lowest cost and highest benefit and there were two alternatives that were True that had the best score.

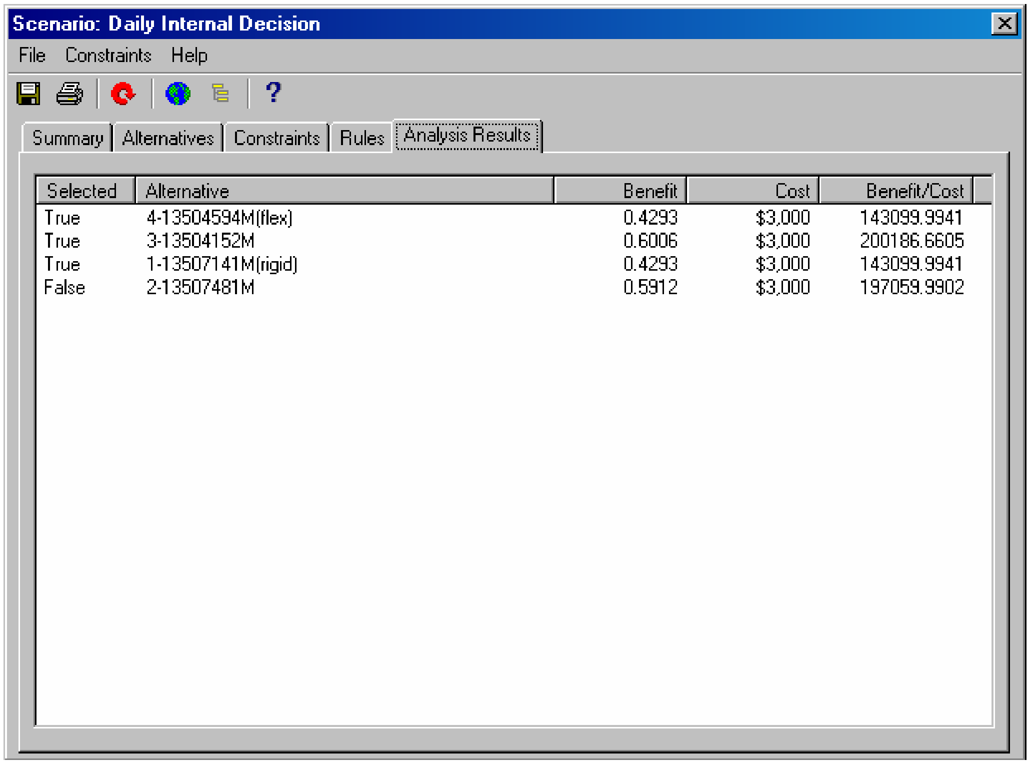


Figure 7.44 – Scenario Results

Since the project was only a technology evaluation of the potential use of RADSS in the PCB area, the benefits of using the RADSS tool as oppose to current manual approach were estimated to be as follows:

- Current daily decision making process takes 30 min.
- Estimated time for RADSS = ~10 min to gather data + ~5 min to enter data + ~10 min to run scenario and make daily schedule = ~25 min total
- Estimated savings per year = (30-~25)/60 * $150(standards hourly rate) * 20(days in month) * 12(months) = ~$3000/yr

7.4.6.4 Recommendations and Findings

After much iteration of refining the decisions model and setting up the problems and scenarios, there were many pros and cons observed with using the RADSS tool.

Pros:

1. RADSS could be used to compile large amounts of data and make decisions on it.
2. The decision development concept was simple and easy to understand.
3. It could result in an approximately benefit of $3000/yr

Cons

1. RADSS 2000 only uses Access '97 to maintain database and import data which makes less usable since LMC computers are typically running the latest Access software (currently Access 2003)..
2. The Graphical User Interface (GUI) is not very user friendly.
3. Entering or importing data is difficult and not suitable for everyday use.
4. RADSS is not flexible or complex enough to handle multiple decision models and scenarios.
5. The software price is too high ($25,000 per license) for limited usage.
6. The source code is not available to customize or modify the GUI.
7. Does not interface with other tools such as Excel or other Access databases.

7.4.6.5 PRADA Pilot Conclusions

The RADSS 2000 tool was analyzed over the two months of this pilot (not including previous training sessions). Originally, Dallas personnel planned to work with PCB manufacturing engineers to use RADSS tool on a daily basis and make modifications to the model to adapt it to their needs. However, due to their busy schedule, the pilot did not get as much support from the PCB manufacturing engineers and the program had to limit the analysis.

However, the POMTT program and Northrop Grumman IT (under a subcontract) worked together to generate the problem sets, create a decision tree and a set of alternatives, and develop scenarios for the pilot. After working on the tool for about a month to adapt to board manufacturing environment, it was concluded that RADSS was not an ideal tool for daily decisions in manufacturing. Even though the tool offered some flexibility, it did not provide enough complexity to take into account all the parameters required for a dynamic system. The concepts such as Resources, Cost, and Benefits that were used in RADSS did not relate well to needed attributes such as employee experience, machine deterioration, machine malfunction, etc.

Section 8

Production Pilots

There were five production pilots performed for the project. They were:

- i2 Technologies' Supplier Relationship Manager (SRM) Life Cycle Prediction of Lockheed Martin Corporation's (LMC) Joint Air-to-Surface Strike Missile (JASSM) Components
- Northrop Grumman Information Technology's (NGIT) Resource Allocation Decision Support System (RADSS) Decision Modeling for LMC's Low Altitude Navigation Targeting Infrared for Night (LANTIRN) / Infrared Search and Track (IRST) System
- Georgia Tech's Physics of Failure (PoF) analysis of BAE Full Authority Digital Engine Control (FADEC) which is used on the C-17, F-35,F-18, and A-10
- EDAptive's Test Vector Generation for Lockheed Martin's TACtical Missile System (TACMS) System Level Test Automation (SLTA)
- i2 Technologies/F/A-22 - Automated Obsolescence Assessment (AOA)

These are detailed in the following sections.

8.1 i2 Technologies' Life Cycle Manager / JASSM

This pilot applied i2's Life Cycle Manager (LCM) tool to the JASSM Missiles Control Unit (MCU) Bill-Of-Material (BOM) to provide online part reviews, automatic BOM monitoring, automatic alert distribution, greater coverage (over 11 million military, industrial, and commercial parts), an 8-year obsolescence prediction assessment, and future integration with the CADIM Product Data Management (PDM) system. Over its 6 month timeframe the pilot focused on analytics, software performance, and usability with the JASSM program and sub-contractors supplying electronics parts data. The benefits (over existing capabilities) that were expected included; fewer design iterations, fewer post-obsolescence events, more effective planning, and better data reporting resulting in cost savings and avoidance.

The pilot consisted of inputting users' data into SRM from the users' PDM or ERP system (wherever the item data resides) and enriching it by adding additional parametric and obsolescence data from VIP. Integration with the users Engineering Resource Planning (ERP) and Manufacturing Resource Planning (MRP) systems was not required but would normally be performed to facilitate data updates from engineering changes and other sources.

The life cycle Electronics Database (ED) (also called Content data), which included all the obsolescence prediction dates, was provided by Semico Research Corporation and now four years of historical data. Prediction accuracy was not reported although it covered a maximum assessment span of 8 years. Also, there was no reported span time (range) provided by i2 Technologies.

The i2 SRM solution is fairly unique since it supports both a Reactive (since the user subscribes to specific part notifications) and Proactive (through the predictive health assessment) obsolescence approach.

It was found that LCM always assumes a user's current inventory is nil and assessments must be modified for parts on hand. SRM also provides an Alternate Component Expert (ACE) which was very valuable in performing searches for alternates.

Finally, the total cost of the I2 tool included the cost of the software, the cost of the Content (obsolescence) data, any integration to external systems (although it does provide a tool and library of interfaces with several commercial tools), and the cost of training and maintenance over the life of the tool.

The overall goal was, and following sections detail the methods that were used, to manage obsolescence on this production program, how the tool could be integrated into the process, its installation, data porting, the actual usage of the tool by the program, and the costs and benefits of the study. The study placed the Life Cycle Manager tool, a part of i2 Technology's Supplier Relationship Manager (SRM), into the Joint Air-to-Surface Standoff Missile (JASSM) production program at Lockheed Martin. The program employed the tool in the management of obsolescence issues in the pilot for six months. As preparation for the pilot, other commercial tools were researched for availability and capability.

8.1.1 <u>Competing Products</u>

The initial task of this pilot was to perform research on other existing and emerging competitors and their products. The following is a summary of this research.

8.1.1.1 <u>i2 Technologies/TACTRAC</u>

i2 Technologies Electronic Database (ED) and TACTRAC life cycle content were previously two separate entities that existed before the Life Cycle Manager and SRM software. The two databases were merged in early 2004 and now the TACTRAC database is included as a subset of the ED database. The TACTRAC tool and database was originally designed to be a standalone resource. The user submits BOMs to the tool and is provided a health report for examination.

i2 Technologies Supplier Relationship Manager uses ED in its enterprise solution for the complete management of the components used in company designs. This means that whenever a BOM is matched against the life cycle Content data, the most current configuration is automatically input into the LCM tool. SRM also supports the ability to create “what if” scenarios with different configurations matched up against the life cycle content. The key differences between TACTRADC and SRM’s ED are contrasted in Figure 8.1.

		ED		SRM
Tool Costs		$ -		$ 750,000
Amortized Cost		$ -		$150,000
Subscription Cost		$100,000		$100,000
Installation Cost				$100,000
Maintenance:				
Hours	120			
Cost		$12,000		$275,000
Training:				$140,000
Run Reports:				
Bills of Materials	400		400	
Times / Year	4		2	
Hours Report	5		1	
		$800,000		$80,000
Examine Reports:				
Hours Report	1		1	
Total Examination		$160,000		$80,000
First Year :		$ 1,072,000		$ 925,000

Figure 8.1 – TACTRAC and SRM Capabilities Comparison

Each of the two tools (ED and TACTRAC) uses different metrics for obsolescence predictions; ED uses Years Till End of Life (YTEOL), while TACTRAC uses both Years Till Unobtainable (YTU) and Years Till Obsolete (YTO) as measures of the respective data points. LCM determines YTEOL at the technology group level, while TACTRAC supports YTU and YTO at the higher commodity level. For example: a technology level could be the ACT technology at a certain feature size while the commodity level could be a 64Kb by 1 bit memory device made with any one of several technologies (TTL, CMOS, etc). LCM predictions are based on factors such as market data, technology, demand, and supply.

The ED life cycle prediction algorithm was reengineered in the second and third quarters of 2003. The life cycle prediction for every component in the database changed. The TACTRAC prediction model is based on statistical component modeling of mortality rates, therefore, when the component is introduced, the end of its life is set to the number of years that items in that commodity generally last. Many parts had been at the end of their life for several years in the database, which implied that the algorithms and models used did not take into account factors that may extend the life of these products. Therefore the algorithm was revised to shorten the maximum look-ahead date to 6 years and accommodate these other life extension factors.

8.1.1.2 PCNalert

The JASSM program, through the Components Engineering team, subscribes to PCNalert in order to receive Product Change Notices (PCNs). The PCNalert is a web-based tool that allows the user to enter a BOM and have the items checked against a listing of PCNs from the manufacturers. The user receives automatic notices when a manufacturer notifies that their part in going to be phased out or discontinued, usually with a built in leeway to allow any last time orders.

8.1.1.3 SHAI (Stottler, Henke Associates Inc.)

Shottler, Henke Associates Inc. started work on an Obsolescence Prediction Tool (OPT) for the Navy in 2000. This software-based tool was an attempt to use artificial intelligence algorithms and techniques to predict the life cycles of parts used in Naval systems. The project was funded over multiple years. However, it never saw adoption by the Navy and no additional research for the OPT was funded.

8.1.1.4 Q-Star

The former CEO of TacTech (Malcolm Baca) founded Qtec Inc. TacTech, the predecessor to TACTRAC, was an independent service and tool that provided life cycle information at the component level. After his non-compete clause ran out Mal founded Qtec Incorporated with its premiere web based tool Q-Star. The tool is similar to the pre-i2 web based TACTRAC tool with additional features to support teaming on obsolescence issues.

Q-Star currently only handles 900,000 active semiconductors and 1.1 million passive devices; however, the company plans rapid expansion of the types and numbers of parts it covers with the tool.

There are three different approaches to using the Qtec tool. The first is through a subscription to their web-based tool. The second is via a private or public system that runs on a dedicated server at the users' facilities. The third option (opted for by the Department of Defense) is to use dual servers with the same reference data on each, with one with one for private and one for public usage.

The tool became available through a one-year subscription in Orlando at the end of the pilot (December 2003) and was used as a crosscheck for parts coverage.

8.1.2 Current JASSM Components Engineering Obsolescence Processes

The JASSM program Components Engineering team supplied the Bills Of Materials for the study program, which included uploading them into the i2 software. The program was in-turn supplied with a BOM health assessment and component life cycle status. This data was then assessed for accuracy by engineering and, if found to be dependable, was entered into the Part Management Database. However, the program historical approach to obsolescence involved a slightly different process and toolset.

Critical and technical data of all active and passive components, including those of the production program subcontractors are stored and monitored through the use of a central database (MS Access). This data includes product change notices (PCN), product life cycle estimates, last time buys, part upgrades and alternates. Technical and part characteristic data such as part description, technology, packaging, moisture sensitivity levels, operating temperature, storage temperature and operating voltages are all stored and updated as needed. Components that have been deemed critical because of their technology application in the product, including those of subcontractors systems, are subjected to additional, periodic construction analysis to validate and monitor any design or performance changes.

JASSM derived its components life cycle data from the commercially available predictive tool TacTech. Managerial and engineering intelligence is then added to this collected data thereby assuring the most optimal paths and solutions are utilized to mitigate obsolescence risk issues. Production program subcontractors cooperated by establishing and maintaining a Parts Management Program for the products they supply.

After manually executing a search on one of the tools, the results are examined to determine the health of each BOM submitted. Items returned with a possible problem are subjected to individual examination by the JASSM Components Engineering staff, which engages the particular manufacturers and suppliers of the part for verification. Obviously, if the report of the component being or going obsolete is false, this is as far as it goes, with the possible exception of notifying the vendor of the database to resolve the issue. If this is not the case then an attempt is made to find the same part from another source. If that is not possible it may be possible to find an alternate that will match the performance specifications of the obsolete part. This will generally require a re-qualification process that can be quite costly and add risk to the program. If the above are not possible it may be necessary to perform a minor or major design change.

If the components that are returned as having obsolescence issues are part of assemblies that are subcontracted items, the subcontractor is notified. The subcontractor then performs their own obsolescence management process with the availability of the assistance from the Lockheed Martin JASSM Components Engineering staff.

8.1.3 Production Pilot Study

The intent of the study was to test the effectiveness of the Life Cycle Manager (LCM) tool from i2 Technologies in a production program at Lockheed Martin. Before the pilot could begin the software had to be installed onto test servers at the Lockheed Martin Missiles and Fire Control facility in Orlando. JASSM was chosen as the production program primarily due to being a new original design that almost exclusively employs COTS components. The design of the study placed the LCM tool into daily use with the JASSM Components Engineering team. Pilot personnel ported BOMs containing listings of the JASSM components of the to the LCM tool's database. The LCM tool then was used with the content data that was updated on a weekly basis to determine the life cycle status of the individual parts. The JASSM Components team employed this life cycle data to make decisions regarding their parts management.

8.1.4 Life Cycle Manager (LCM)

The Life Cycle Manager (LCM) was originally a standalone tool created by Aspect Development Inc. Aspect was bought out by i2 Technologies early in 2000, along with other tools and software products produced by Aspect. Included in the purchase were Aspect's Explore™ products, which were specifically designed with features for maintaining and using relational databases.

i2 Technologies bundled the Explore™ technologies, the LCM tool and their knowledge of supply chain management into a suite of tools call Supplier Relationship Manager (SRM). They used SRM to extend their collection of developed and acquired software tool capabilities. In order to examine the value of their life cycle management capabilities it was required that SRM and the support software be installed. The version of SRM used in this pilot study was SRM 6.0.1.

8.1.5 Supplier Relationship Manager (SRM)

SRM uses the imbedded Explore™ relational database technology to maintain user data on parts, components, corporate parts, assemblies, and other required information for parts management. SRM is promoted as a complete system for managing parts and materials for a manufacturing environment. Its goal is to manage information from the design phase, to product sourcing through to the procurement of any item.

8.1.6 Electronics Database (ED)

The Electronics Database extended i2 Technologies' older and smaller database called Very Important Parts (VIP) to include life cycle content. The life cycle content obtained from TacTech was used as a starting point for VIP in two databases: one for commercial parts and one for military parts.

As of the end of the project, the ED contained data on over 11.1 million parts from approximately 1000 manufacturers including commercial and military components. The military portion of the database contains information on approximately 413,000 military specified parts along with links to the corresponding Mil-Spec. ED contained individual records for over 4 million parts including approximately 1.7 million of those with detailed life cycle content, which have life cycle predictions, and 2.4 million of those for parts with basic life cycle content, which only have general obsolescence information. This is summarized in Table 8.1.

Table 8.1 - ED Statistics

Parts	11.1 Million
Manufacturers	>1000
Military Parts	>413,000
Parts with Life Cycle Content	4 Million
Parts with Detailed Life Cycle Data	1.7 Million
Parts with Basic Life Cycle Data	2.4 Million

8.1.7 Requirements Development

Lockheed Martin participated in a review of i2's Software Requirement Specification (SRS) for the Supplier Relationship Manager Life Cycle Module (LCM) in November, 2000. This was the first real insight POMTT had into what LCM would do. The document was difficult to understand, primarily because of limited formatting, but overall the content and approach to be very well thought out and detailed. It includes a DMS input and review system that automates existing methods of emailing DMS notices to each program, and tracks and retains reviewer responses. i2 defined a 5 color coding system (Green, Yellow, Orange, Red, and Blue) to identify the level of obsolescence, where most companies currently use a 3 color system (Green, Yellow, and Red). Health assessments (risk/obsolescence projections) could be performed on a specific part, or an entire program, and could be projected over a program's lifespan. The cost/benefit tradeoff analysis was also unique and looked very promising.

The methodology was as follows:

1) *Data Collection* - Identify, input, and analyze part level DMS notifications and solutions

2) *Health Assessment* - Classify (color code) individual parts, cross reference, and identify solution options

3) *Cost Estimate* - Input program needs/constraints, aggregate parts by program, project over program lifecycle, and determine solutions

4) *Analyze Costs* - Project the total costs by year and provide a comparison

The color code definitions were:

Green - Low risk, 2 years or better of forecasted availability

Yellow - Medium risk, 1 to 2 years of forecasted availability

Orange - High risk, less than 1 year of forecasted availability

Red - Currently obsolete

Blue - Parts excluded by the user from analysis, incomplete/incorrect part numbers, program action required

However, a number of issues, concerns, and suggestions were provided back to i2 for their benefit. These include:

1) How will the DMS notices be input into the system?
2) How does a LCM-generated DMS alert get initiated?
3) Will each DMS alert reviewer and program be required to input their solution/decision, and how will they be captured?
4) Why give the user the ability to edit/update the Bill-Of-Material (BOM) data?
5) Why give the user the ability to edit the LCM reference data? Should this only be an input capability (if not previously existing)?
6) Are the alternative options and solutions processes (part comparisons, searches, replacements, and sourcing) currently available in eDesign, or will they only exist in the LCM?
7) What limits will be placed on the user's ability to modify the algorithm?
8) How can differing program constraints be included (e.g. long term missile storage versus long term electronics service life)?
9) Are the part level solution options only for those items identified as currently obsolete (red)?
10) Do the DMEA cost factors accurately match our requirements?
11) Are the costs for future years adjusted (i.e. for inflation, etc.)? If not, can they be adjusted or must that be done using the cost factors edit capability?
12) Will LCM capability be provided to calculate the difference between Total Ownership Cost solution options?
13) Are both parts with replacement options, and without replacement options, included in the cost assessment?
14) What parameters are being evaluated for input into the prediction algorithm?

The approach was, at the part level, almost exactly the same process used in Orlando, except that Missile and Fire Control’s process is manual and very time-consuming. The system level perspective provides a capability that Orlando did not have and looked to be extremely valuable for program decisions. The document, though, appeared to have been written without a complete understanding of the eDesign system, so expectations as to the LCM's capability were tempered. Additionally, there are no details provided (from even a general perspective) on the actual obsolescence prediction algorithm so verification of the modules analysis and results would be required before use. However, if the level of automation exceeds that of the data input and maintenance, and the accuracy of the prediction algorithm is verified, then the module should be extremely valuable.

8.1.8 Installation

The Life Cycle Manager tool required a large amount of software to be installed in support, and as part, of the tool before it could be examined. The LCM tool, the principle instrument to be considered, is part of a much larger system. It performs the analysis of the Bills of Materials (BOMs) for the production program. The LCM tool is now part of larger software suite called Supplier Relationship Manager (SRM). SRM provides resources for managing parts lists, corporate parts catalogs, life cycle content along with cost data for components and materials. A significant portion of this suite had to be installed in order to use LCM.

8.1.9 Software

The entire SRM suite requires a stack of middleware to function (see Figure 8.2). These web and Java-based interfaces protect the user from the complexity of the product by presenting a relatively simple unified interface to the user. One of these, BEA's Weblogic application server, is necessary to run the JAVA 2 Enterprise Edition (J2EE) interface. J2EE is a SUN Microsystems platform independent suite of enterprise level software. It provides support for the client-server portion of the application.

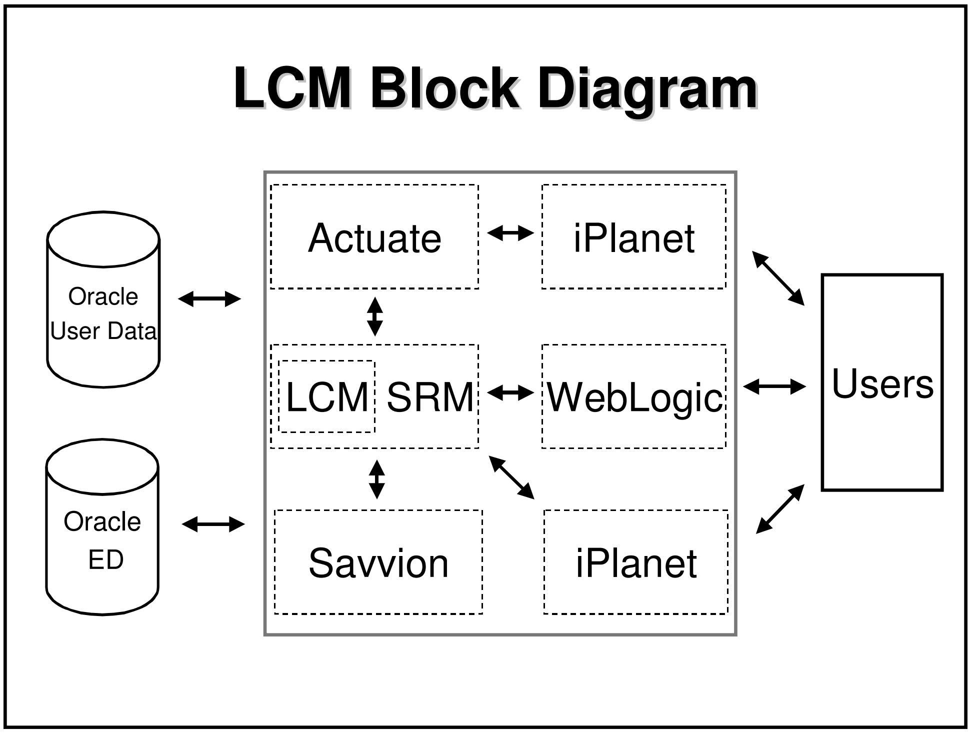


Figure 8.2 – Life Cycle Manager Block Diagram

For this installation an Oracle instance was used as the database application. i2's solution supports DB2 as the alternative. The Oracle instance contained two separate databases. The first was for the user data and the configuration data that the SRM application keeps. The second but most crucial part of the study is the Electronics Database (ED), formerly called the Very Important Parts (VIP) database. The ED tables store information on over 11 million commercial and military parts, of which over 3 million have lifecycle content.

The Actuate reporting suite is required in order to print reports. The installation necessitated the need for two different versions of Sun's iPlanet Webserver: one version for Actuate and the other for SRM itself. These provided the web-enabled portions of the tool the necessary middleware to operate.

The SRM installation also required the Savvion Workflow Manager. It provides the processes that a more largely employed system would require to route part issues through the responsible parties. For example: if one were to put a part into the system for approval it would be distributed to all the proper parties in the necessary order for approval.

The installation of the software took one week, with an extra week to resolve two installation support cases. However, the installation did require the assistance of two i2 support personnel for one week as well as a LMC DBA for system level support.

i2 Technologies provided three basic templates of installation, those being User, i2 Assisted, and i2 Fully Supported. The User model requires the user's organization to install the software and to port the data entirely using the organization's resources. The i2 Assisted model may have some on site support while the data is usually sent to an offsite facility to be ported to the new tools. There are two sites available: one in India, and the other in Mountainview, CA for databases that cannot leave the country due to export restrictions. The i2 Fully Supported model has all of the tasks being turned over to i2 Technologies' staff to create a turnkey solution for their customer, but is also the most expensive.

8.1.10 Electronics Database (ED) Installation

The ED was originally not available for an HP UNIX installation; after a couple of months it arrived on a DTL tape. The content took up over 70 GB once the installation was complete. The preferred installation for this arrangement is to run two separate databases with a trace file to make the two databases seem as if they are one. The installation took one week and required the support of one of Lockheed Martin's Database Analysts for two of those days. In order to get reasonable response times for data access and application performance the database was installed on a separate machine from the web and application server. This does not include the effort for porting data or installing the ED. For most customers, i2 Technologies reports a normal installation time of approximately 3 months. For the JASSM Pilot, the ED database took approximately 1 week to install and required two support cases that took an additional two days to resolve.

8.1.11 Hardware

As can be seen in Figure 8.3, two servers were employed for the study installation. The first machine ran all the application software except for Oracle. It has a 660 MHz processor with 640 MB of memory. The second machine, which exclusively ran the Oracle instance, has dual 550 MHz processors and 512 MB of memory. The installation took approximately one week and required the full time resources of the pilot lead, two i2 installation support staff, and the part time assistance of one of Lockheed Martin's staff DBAs. It should be noted that this was a limited installation and had reduced requirements for performance, due to the low user volume.

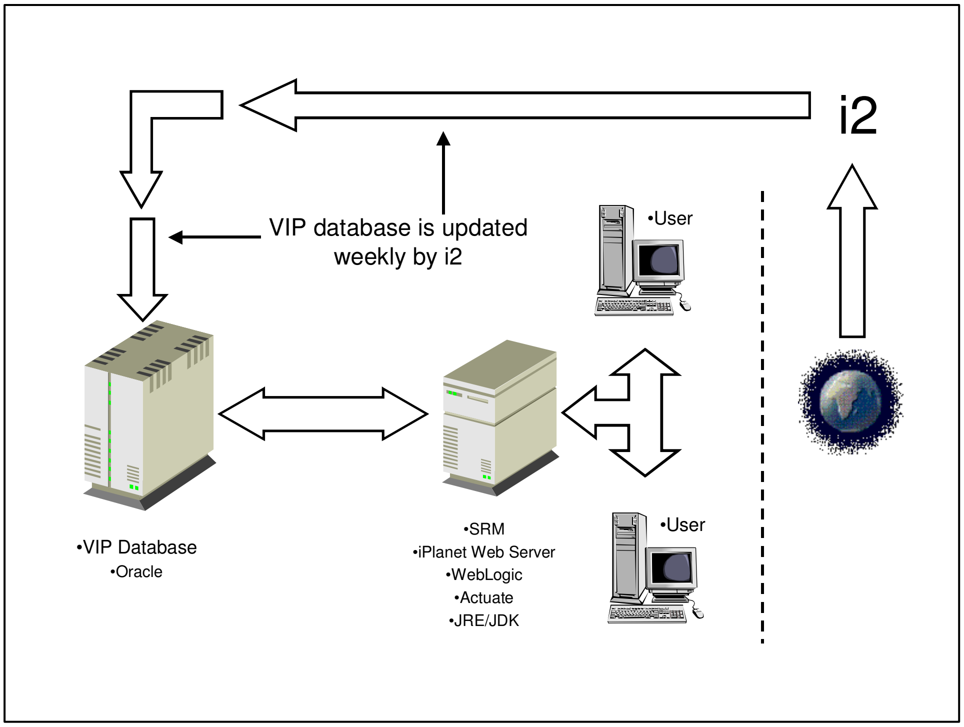


Figure 8.3 – i2 Pilot Hardware Diagram

8.1.12 Data Porting

For the purposes of this study only active parts were evaluated. For example: the total number of actives was required to fit the license restrictions of 500 total parts. Also, lifecycle data for passive devices would not be available until the beginning of 2004 and commercially available active parts were more likely to change status during the study.

The data originated from three distinct sources: program assemblies, subcontractor supplied, and physical hardware examinations. For assemblies directly manufactured by Lockheed Martin an accurate and current BOM from the existing release drawings was supplied by the Components Engineering team. The JASSM Components Engineering team persuaded many of the Lockheed Martin subcontracted vendors to make available the BOMs for their assemblies. The last set of BOMs was acquired from physical, hands on examination of the assemblies themselves and was considered the least accurate.

8.1.13 Field Matching

Data from the JASSM program was ported into the tool in a multi-step process. First, various techniques were used to transfer data files to Neutral File Format (NFF) using a pipe "|" delimiter between fields. At the very minimum, the required fields were "Manufacturer" and the "Manufacturer's Part Number"; however, many other fields such as "Corporate Part Number" and "Part Description", as well as several others were often available. Depending on the source of the original dataset, different types and amounts of data were available for each assembly thereby providing varying fields available for import into SRM. In order to load these NFF files into the tool, the correct mapping of the originating dataset field to the SRM dataset field was required. Loading orders provided this mapping for the originating fields and data types from the available datasets to the user data portion of the database. A slightly different loading order was created for each of the available dataset sources depending on the available fields in the originating database. SRM 6.0.1 does not have a utility for porting data directly from a Microsoft® EXCEL file; however, a newer version of SRM reportedly includes this feature.

8.1.14 SRM 6.0.1 Relevant Data Model Items

In the SRM 6.0.1 data model the assembly items are generated through the addition to a BOM of an instance of the *Corporate Part* class (see Figure 8.4). This is a leaf class of the *Item* class, which corresponds to internal item representations in the database. *Item Specification* records containing the manufacturer and the manufacturer's part number are linked to *Corporate Part* records through an intermediate data class called *Item to Item Specification*. The *Item Specification* class contains a pointer to the *Part – VIP* class, which can be used to identify the corresponding VIP record in the ED. It is only through the actual matching of the *Item Specification* instance to an instance of the *Part – VIP* class that the life cycle data is brought into the Life Cycle Manager tool. Instances of *Part – VIP* class contain specifications for the part, as well as provide links to datasheets and other supporting documentation.

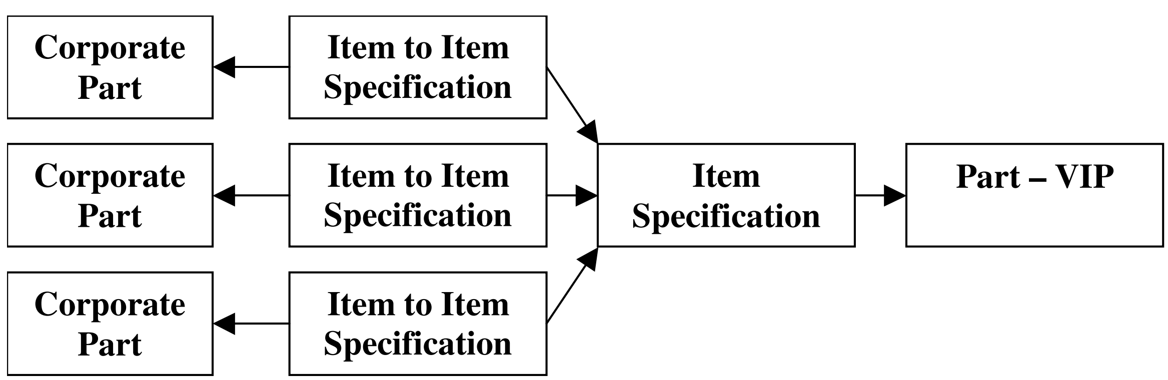


Figure 8.4 – Item Class Relationships

8.1.15 Component Matching to Life Cycle Records Process

In order for the LCM to function, the fields in the *Item Specification* instance, which resides in the user portion of the database, must point to an instance of the *Part – VIP* class part life cycle content in the ED. This was accomplished in several steps; first, the porting provided the initial set of recognized parts. Due to technical limitations, these matches were required to be exact matches to manufacturer part numbers. Second, those parts that were not automatically matched had to be manually matched to the ED content.

There were several reasons for a part not matching the ED data including: some suffix combinations were not included in the ED, part data was missing for an item of a manufacturer's line, and life cycle content was not available for the part in review. Third, any remaining unmatched parts were then reviewed with the production program team, with special attention placed to the suffixes. This provided another round of manual matches that recognized most of the remaining unmatched parts.

An unintended benefit arose from this process of matching the part numbers to the *Part – VIP.* Small errors in the part numbers that were in the original program database were corrected as the parts were placed in the SRM database. This part number normalization removes the possible ambiguities for better configuration and document control and can act as a double check on manually entered part numbers. Of course there were part numbers that had sequences that were not represented in the database for a particular vendor.

Using i2's support website, a case for content was created for part numbers from specific manufacturers that were missing or were devoid of life cycle content. The work to resolve these content issue cases is completely performed offshore in India. These cases were resolved in an average of a little less than 1.5 weeks per case and the necessary changes were generally available in the next week's content update.

8.1.16 Database Updating

To keep the life cycle data up to date, weekly content updates to the ED were provided by i2 and applied to LMMFC-O's system. The content files were File Transfer Protocol (FTP) transmitted to the server manually. The files were around 21MB compressed, and completely unzipped they were typically from 150 to 300 MB. i2 Technologies provided Content Update Loader (CUL) tools to be used specifically with the database to load the data. The loading script from the CUL tools takes from 1.5 to 4.5 hours for each update but, once started, is completely automatic. After the ED has been updated a small handful of scripts must be performed to update the user's parts database life cycle ratings. Once this process becomes part of the general routine of the database manager it only takes around 30 minutes of effort a week.

8.1.17 Data Analysis and Reporting of Results

Each week during the run of the pilot study the ED was updated, LCM analyses of the BOMs were performed and meetings with the participants occurred. This continued for the entire duration of the six-month study.

The LCM analyses were performed each week after the database was updated and reports of the status of the items on the various BOMs were created. These reports were then compared to the initial baseline as well as prior week's reports. Changes to the status of items on the report and other items of interest were recorded.

8.1.18 <u>Weekly Meetings</u>

Weekly meetings were held with a JASSM Components team member to discuss items on the trade study as well as any changes that occurred to the status of the items of the BOMs being monitored.

8.1.19 <u>Component Issues</u>

During the course of the pilot study several issues with different components arose. Although the tool was relatively automatic once installed, the JASSM Components Engineering team first had to determine the nature of the issue with the component and then verify the accuracy of the reported information. If the suspect component has a reported End-of-Life (EOL) notice, or was given a Phase-Out rating, the tool reported that a short time will elapse before the part number and manufacturer combination will be reported as discontinued. The Components Engineer responsible for the BOM was then required to investigate these parts by contacting the manufacturer and suppliers to ascertain the disposition of the part.

One possibility, though not observed in this pilot, was that the part was still available and would continue to be so from the manufacturer, with no change. This then required the program to provide i2 Technologies with the inaccurate information and submit a request to have this researched through a Content Research Request which are included in the ED subscription. The Research Request had i2 Technologies' support staff find traceable documentation to verify if the information being reported was incorrect. However, if it turns out that the component will no longer be produced, other actions must be considered.

Another possibility encountered was that the production of the part had been sold to another manufacturer. Depending on the circumstances this may require a considerable requalification effort. If the component will no longer be produced an alternate part may be available that will serve as a suitable substitute. The alternate part finder portion of the SRM tool can be helpful in finding alternates. More drastic measures may be required to resolve obsolescence issues. If either the manufacturer and/or the part number that will be used change, then the creation of a new *Item Specification* will be required along with linking it to the *Corporate Part* with a new instance of *Item to Item Specification*.

8.1.20 <u>Reports</u>

The SRM software provided the capability to generate reports either using existing templates or with the Actuate reporting program.

8.1.20.1 <u>Life Cycle</u>

The primary report of the LCM is the “BOM Obsolescence Health Report: Lifecycle status” an example of which is shown in Figure 8.5.

BOM Obsolescence Health Report: Lifecycle Status

Assembly Name:	**PC (ACTIVES)**
Assembly Rev:	**A**
Scenario Number:	
Number of parts in assembly:	**17**
Number of parts with Lifecycle data:	**17**
Report date:	**Dec 1, 2003**

Life Cycle Status	Best Case Parts		Worst Case Parts		MPN		Alternate MPN	
	Qty	%	Qty	%	Qty	%	Qty	%
Unknown	0	0.0	0	0.0	0	0.0	17	100.0
Introduction	0	0.0	0	0.0	0	0.0	0	0.0
Growth	1	5.9	1	5.9	1	5.9	0	0.0
Mature	14	82.4	13	76.5	12	70.6	0	0.0
Decline	2	11.8	2	11.8	2	11.8	0	0.0
Phase-Out	0	0.0	0	0.0	1	5.9	0	0.0
Discontinued	0	0.0	1	5.9	1	5.9	0	0.0
Transferred	0	0.0	0	0.0	0	0.0	0	0.0

Figure 8.5 – BOM Life Cycle Status Report

The top of the report contains the basic header information including assembly name, revision, part counts and the date that the report was run. The table in the middle of the page summarizes the counts of the life cycle status of the elements in the BOM for the Worst, Best and Actual cases. The bottom of the first page of the report also provides pie charts with graphical representations of the information presented in the table. The "Best Case Parts" column describes the statistics both by quantity and by the life cycle status for the best possible "Item Specification" life cycle rating for each of the "Corporate Parts". The "Worst Case Parts" column does the same for the worst case for each of the "Corporate Parts". The statistics for the selected Part Numbers are shown in the third column.

Figure 8.6 is an example of the remaining pages in the report that itemize the parts included in the BOM, in order by corporate part number. Highlighted in red is a corporate part that has two *item specification* records associated through an *item to item specification* record. Both of these records are considered to be under the same corporate part number even though they have slightly different manufacturer's part numbers and are used to make up the Best and Worst cases for the BOM health report and graph as seen previously in Figure 8.5.

Level	Part Number	Qty	Description	Line Number	MPN	MPN Description	Manufacturer	LC Status	YTEOL	Data Source	LTB Date	LTD Date
1	Part #1	1	MKCT, DUAL – D TYPE FLIP FLOP	18	VPN #1		TEXAS INSTRUMENTS INC	MATURE	6	i2		
1	Part #2	0	MKCT, POWERPC PROCESSOR (MOTOROLA)	20	VPN #2		MOTOROLA INC	GROWTH	6	i2/TACTECH		
1	Part #3	1	LOW SKEW CLOCK DISTRIBUTION	21	VPN #3		MOTOROLA INC	MATURE	6	i2/TACTECH		
1	Part #4	1	SINGLE BIT TRI-STATE BUFFER	22	VPN #4		FAIRCHILD SEMICONDUCTORS	DISCONTINUED	0	MANUFACTURER		
					VPN #5		FAIRCHILD SEMICONDUCTORS	MATURE	6	i2/TACTECH		
1	Part #5	1	BOOT BLOCK FLASH	23	VPN #6		INTEL CORP	MATURE	3	i2		
1	Part #6	1	600 K GATE FPGA	25	VPN #7		XILINX INC	MATURE	6	i2		

Figure 8.6 – BOM Life Cycle Details

8.1.20.2 Other

Other reports can be output from the tool using the Actuate client or by exporting the results of a search to an Excel™ spreadsheet. Examples include BOM explosion, single item list and with the proper software add-on user customizable reports.

8.1.20.3 Graphs

The LCM provides a useful set of graphing utilities that are used to display the life cycle data in various ways such as the graph (Figure 8.7) which illustrates the risk associated with various parts (shown on the left) over the time period axis on the bottom. The horizontal bars illustrate the estimated Years until the End Of Life for the various parts. For example the first line shows that for the first year the part will have greater than 11 Years until the End Of Life. From one year until six years the part is expected to have greater than 6 years until the end of its life. All of these predictions come from the ED life cycle content and obviously provide no guarantee, but do present an estimated level of risk of a certain part becoming obsolete.

Figure 8.7 – Life Cycle Comparison Bar Chart

Another type of graph provided in Figure 8.8 shows the relative proportion of the parts of a particular BOM that are in a particular life cycle phase. Also, due to the ability of the tool to allow for many alternate parts for a single line item in a BOM the best and worst case for the available parts can be compared side by side as in the following graph:

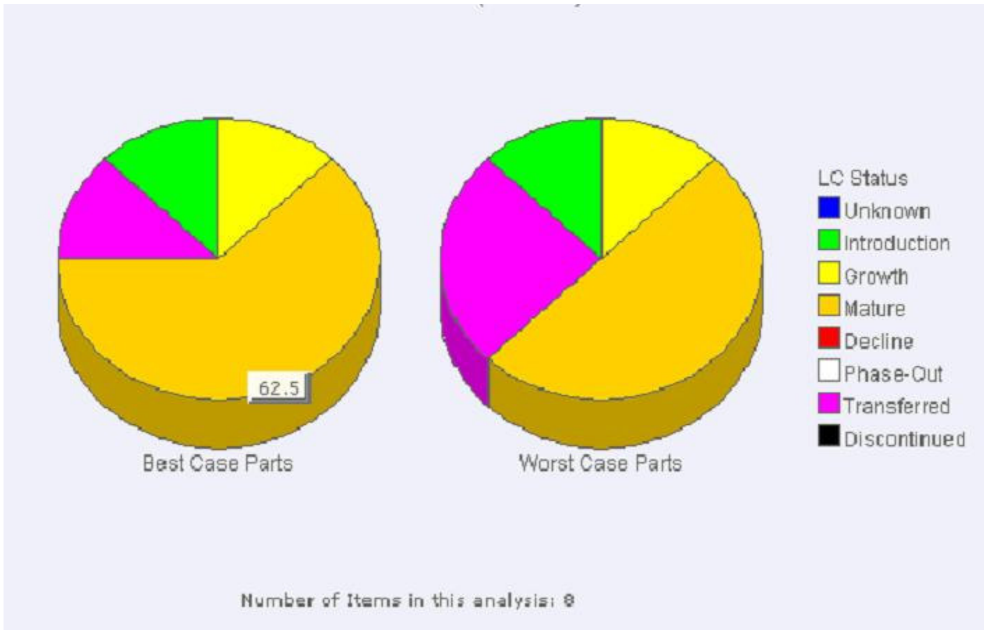


Figure 8.8 – Life Cycle Comparison Pie Chart

8.1.21 Training

Training was performed on an abbreviated schedule, and with an abridged curriculum. For this product set, i2 Technology normally recommends one week for general user training and three days for super user training. A member of i2 Technologies Educational Services team performed the training at the Lockheed Martin Missiles and Fire Control Orlando facility. Training was hands-on using laptops running a truncated version i2 Technologies SRM software. The instructor tailored the course material for the training sessions to the particular needs of the pilot participants. The course material included the specially tailored text and was accompanied by the corresponding slides. The i2 Technologies trainer was well informed and extremely organized. The instruction was generally well received and garnered good reviews.

8.1.21.1 User Training

The user-oriented training took place on the first day and was intended to give a summary overview of operations necessary for the successful completion of the pilot. It included an introduction to SRM Product Sourcing, the SRM home page, basic searching and basic editing. The course continued with training on building, importing and exporting designs. The final 3 hours of the course was spent discussing the Life Cycle Manager including the various features of the tool.

8.1.21.1 Administrator Training

The administrator-oriented training was held on the second day to give a more detailed understanding of the tool and supervisory functionality. The course covered navigating relationships, data editing, forms management and tools for importing and exporting Bills of Materials. The instruction also included managing users, user groups and the associated permissions and relationships for each. The last two hours were reserved for a white board discussion of the design relationships and an overview of the data model used by SRM.

8.1.22 i2 Support

i2 Technologies provides several methods for delivering support with their products including on site visitations, phone based, and web based.

8.1.22.1 On Site

i2 Technologies' provides on site support in two forms: either as a visitation or as a semi-permanent on site consultant. This pilot study had two i2 support staff visit the Lockheed Martin Missiles and Fire Control Orlando Sand Lake facility in order to assist in the installation of the software. They were quite knowledgeable on the installation process as well as the rest of the SRM suite. They had information on undocumented features of the tools as well as experience installing the software on many other platforms. If there was a question that they did not have an answer for they knew who to call and how to get support. Their presence also facilitated a more intimate understanding of the software to the pilot team.

The other form of support places a member of the i2 support staff on-site to solve problems as they come up and act as a liaison with i2. Many of i2's support staff are not citizens of the United States however, so it is important to be cognizant of this and other potential issues that may be present and communicate these to the i2 customer service staff. This can present a problem depending on the nature of the facility and the organization.

8.1.22.2 Phone

It is also possible to call i2 Technologies and create a support case by phone; the support staff will generally try to contact their customers by email initially for smaller problems but will contact their customers by phone for issues such as system downtime. They will also contact their customers by phone for larger more involved problems that cannot be easily remedied by email. In the pilot, calls for support that involved the JAVA client, the web based interface, and the servers originated in the United States and generally were from Texas. Calls for support involving the management of the database originated from India. India is 10.5 hours ahead of the eastern United States and this can create a logistics problem when trying to contact support staff. In order to resolve an issue regarding the updating of data the pilot staff had to be available at 6:00 AM to receive the support calls from India. However, the support was competent and it did facilitate the resolution of the issue.

8.1.22.3 Web Based

i2 Technologies' preferred method of support delivery is through the use of their support web site and email. i2 Technologies' support web site makes it possible to enter a case with similar effort required to create an email. The support system sends emails to update the initiator on the course of the case from confirmation to case closing. When necessary a member of the support staff will call the user to assist in resolving an issue.

8.1.22.4 Support Classification

Support cases are classified using two characteristics within a certain product line such as SRM or ED. The first characteristic is the case type for instance this includes installation, client-server and content issues. The second characteristic is severity of the issue and ranges from 1 to 4. 1 stands for critical system downtime cases and 4 is for minor cases. Cases that are classified with a 1 or a 2 will initiate a call within the hour to the customer to ascertain the nature of the difficulty. If it is determined that the case is not as severe as the customer reported the case with be reclassified with a lower severity number. If it is as severe as was previously reported i2 support will route the necessary resources to the customer. If a lower level case continues for an extended period of time the case can be escalated by a request in the web based support system or by a phone call to i2 support.

8.1.22.5 Support Escalation

If there is an issue that has not been resolved to the customer's satisfaction the system allows for the escalation of the case. The support team assigns a "Customer Success Manager" to the case and closer contact with the customer is maintained. The "Customer Success Manager" acts as a personal liaison with the support staff and endeavors to expedite the necessary assistance to the user.

8.1.22.6 Content

Content support cases involving issues with data in the ED, which is managed offshore in India, require a little more planning for resolution. When an error, omission or question about content in the ED arises the user can enter a content research request on the support web site. The ED may have a record that shows the incorrect availability of the part (i.e. may show that a part is unavailable when it is or vise versa). The part number for the manufacturer may not be available in the ED due to an omission or a technology transfer to another manufacturer. The content support team will research the issue with the component and determine the adjustment to the data if any is required. In order to determine the status of a part there must be a traceable resource from the manufacturer, which is recorded for control purposes.

8.1.23 Other Integration Features of SRM / LCM / ED

SRM is designed for tight integration with i2 Technologies' other products; it also provides for integration with systems provided by other vendors such as SAP. The

Lockheed Martin Missiles and Fire Control has integrated their Product Data Management (PDM) system with the older Explore™ client.

The search functions allow designers to find alternate parts or find parts with desired specifications. Once the part is found the quick link to the manufacturer's web site as well as access to the manufacture's data sheets, part change notices and other documentation in the tool allow for the quick determinations of the suitability of a component.

8.1.24 Electronics Database (ED) Life Cycle Model and Other Data

A brief explanation of POMTT's understanding of i2's data model is provided in the following sections.

8.1.24.1 Life Cycle Stages (Obsolescence Model)

The model used by i2 Technologies ED for life cycle prediction uses both a numeric prediction as well as a nominal/ordinal description of the stage in the life cycle. The tool classifies the life cycle stage of a part into phases, those being: Introduction, Growth, Maturity, Decline, Phase-Out, and Discontinued.

In Table 8.2, the Introduction stage the component is new to the market and should be produced for several more years. During the Growth stage there is an increased demand for the part and there may be more than one manufacturer. The Mature stage sees steady demand and supply for several years with little or no change. The Decline stage is marked by a reduction in the number of manufacturers and demand of the component. It is expected that during this phase that the manufacturer will issue a notice indicating an end of production. Phase-Out comes after the manufacturer has issued this notice. Finally, the Discontinued stage indicates that the manufacturer is no longer producing the component. The tool also has a Discontinued-Transferred category for those items whose production has been transferred from one manufacturer to another.

Table 8.2 – LifeCycle States

Life Cycle Stage	Description	Availability	Risk
Introduction	Product has been newly introduced to market	Limited number of suppliers or sole source	High
Growth	Product finding niche in the market place, growing number of adaptors	Increasing number of sources and higher production	Moderate
Mature	Steady supply and demand of the product for many years.	Steady availability for several years	Low
Decline	Product experiences reducing demand	Diminishing number of Sources	Moderate to High
Phase-Out	Manufacturer has issued notice of discontinuation	Limited	Extreme
Discontinued	The manufacturer no longer produces the part.	None or After Market, generally extremely expensive	Extreme

8.1.24.2 <u>Years Until End of Life (YTEOL) Predictions</u>

In concert with these life cycle stages i2 Technologies' proprietary algorithm produces a numerical estimate for the remaining years until end of life (YTEOL), which also resides in the ED and is used in the reports. During the third quarter of 2003 the prediction model was altered in an attempt to better match the actual results from i2 Technologies' experience over time. These changes in the algorithm were announced at the i2 Planet Conference in 2003. The time spans of all the prediction levels were reduced because i2 determined that it was not possible to accurately predict out as many years as they were doing. On a proprietary level, the models that are used for each commodity were customized to match the historical lifecycle characteristics of the commodity (e.g. a memory device was expected to have a shorter life than an operational amplifier). The lengths of the predictions were shortened for every single part in every single category.

8.1.24.3 <u>Availability of Datasheets, Links and Alternates</u>

The ED has part data on over 11.1 million parts including supporting documentation such as datasheets, application notes, and Part Change Notices (PCN). There is also a link for virtually every part (>99%) to the manufacturers' web page. The tool also allows the user to search for alternate parts based on a variety of different parameters including technology, type, packaging, and voltage.

8.1.25 Results

The results are divided into two sections: Primary Results and Secondary Results.

8.1.25.1 Primary Results

The primary results include Data Matching, Data Changes, and Itemized Changes.

8.1.25 .1.1 Data Matching

When the parts were entered and matched with the loading process 69.1% of all the parts matched to the ED. After removing all the passive devices, connectors and other hardware the percentage for the parts coverage went to 76.8%; when the parts lists were limited to BOMs that were under the direct control of Lockheed Martin the parts that matched initially went up to 86.1%. Upon using the matching process described in the previous sections the matched percentage for the BOMs under Lockheed Martin control went to 98.7%. In order to do this the support cases described above were used. These are summarized in Table 8.3.

Table 8.3 – Data Matching Comparison Chart

TACTRAC	SRM	Qtec
76.8%	86.1%	40.2%

Comparing the initial recognition of parts between TACTRAC, SRM and Qtec reveals that SRM initially recognized the most parts from the BOM with 86.1%; TACTRAC initially recognized the second most parts at 76.8% and Qtec the least number of parts at 40.2%. This is consistent with i2 Technologies claim that the TACTRAC database is a subset of SRM, and QStar's corporate statement that Qtec is still increasing the parts coverage of their database. Taking all the of the parts that were recognized by SRM and uploading them to the Qtec tool the percentage of recognized parts goes up to 71.2%.

At the end of the pilot study the majority of the parts were in the desirable range for life cycle (Growth and Mature). These are summarized in Figure 8.9.

Life Cycle Status	Totals	%
Unkown	1	1.32%
Introduction	2	2.63%
Growth	2	2.63%
Mature	65	85.53%
Decline	3	3.95%
Phase-Out	0	0.00%
Discontinued	2	2.63%
Transferred	1	1.32%
Total:	76	100.00%

Figure 8.9 – Life Cycle Status Summary

8.1.25 .1.2 Data Changes

Figure 8.10 illustrates how some of the parts changed status during the pilot.

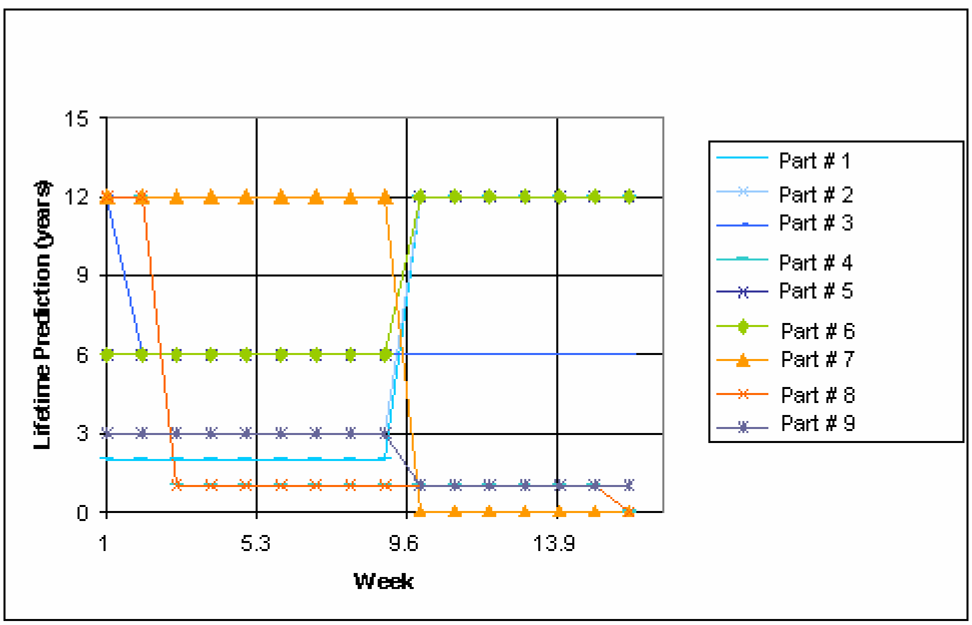


Figure 8.10 – Lifetime Prediction versus Weeks

Using only the matched parts lists under the direct control of Lockheed Martin it was observed that 43.5% (81/181) of the parts on the lists changed life cycle status during the pilot. The majority of these changes were due to the announced transformed data model that predominantly lowered the life cycle prediction for all the affected parts.

Parts, which changed due to something other than the considerable overhaul of the life cycle model, were limited to 8 out of the 181 parts for a percentage of 4.42%.

8.1.25 .1.3 Itemized Changes

Some examples of some parts that underwent changes to their status are as follows:

Part #1 is a Two – Terminal IC Temperature Transducer manufactured by Analog Devices that had a life cycle predicted to be 2 years however, on 11/13/2003 it was upgraded to 12 years life cycle.

Part #2 is a 22-Bit Data Acquisition System manufactured by Analog Devices that had a life cycle predicted to be 3 years however, on 11/13/2003 it was upgraded to 12 years life cycle.

Part #3 is a Dual D Flip-Flop manufactured by National Semiconductor was transferred to Fairchild Semiconductor on 9/9/2003. The life cycle prediction was 12 years downgraded to 6 years. The program processed the necessary paperwork to change the approved manufacturer for the component.

Part #4 is a Temperature Compensated Zener Reference Diode from Compensated Devices Inc. The part was downgraded from 12 years to 1 year and on 12/08/2003 to 0 for that manufacturer. It was transferred to Microsemi Corp on 9/22/2003. The program processed the necessary paperwork to change the approved manufacturer for the component.

Part #5 is a Quad CMOS Differential Line Receiver manufactured by National Semiconductor with a life cycle prediction that on 11/13/2003 went from 6 years to 12 years.

Part #6 is a 3V Enhanced CMOS Quad Differential Line Driver manufactured by National Semiconductor with a life cycle prediction that on 11/13/2003 went from 6 years to 12 years.

Part #7 is a 3-to-8 Line Decoder manufactured by National Semiconductor that the life cycle content went from 12 years to 0 years because it was transferred to Fairchild Semiconductor Corp. on 11/13/2003. The program processed the necessary paperwork to change the approved manufacturer for the component.

Part #8 is a Dual Non-Retriggerable Monostable Multivibrator manufactured by National Semiconductor that had life cycle of 12 years that was downgraded to 1 year on 9/22/2003 and then down to 0 years on 12/08/2003 because it was transferred to Fairchild Semiconductor. The program processed the necessary paperwork to change the approved manufacturer for the component.

Part #9 is a 3 Volt Advanced+ Boot Block Flash Memory manufactured by Intel with a life cycle content that went from 3 years 11/07/2003 to 1 year on 11/13/2003 with last time buy dates and a Phase-Out rating. A suitable alternative was identified, the new part was requalified and the necessary processes were followed to change the part in the BOM.

8.1.25.2 Secondary Result

Using this tool required that the part numbers be normalized to a known standard set of part numbers that are matched up to the life cycle content. This part number normalization was a secondary result of the pilot process and is expected to help reduce costs by preventing incomplete or incorrect part numbers from proliferating through the supply chain and the production process.

8.1.26 Cost Trade Study

During the course of the JASSM Pilot program a trade study using a Cost as an Independent Variable (CAIV) approach was developed in order to supplement other information from the pilot. The specific tool used was Dynamic Insight © 2000-2002 by James Gregory Associates (Version 1.0.7). The Pilot team held weekly meetings to determine the requirements matrix and the desired values.

The requirements were split into 3 types: Performance, Programmatics and Total Ownership Cost (TOC). The Performance requirements dealt with how the tool behaves such as part recognition and prediction accuracy. The Programmatics requirements identify how the tool affects a program that uses the tool. The TOC reflects the amortized over 5 years cost of using the tool. The following Table (8.4) shows the requirements that were used in this trade study:

Table 8.4 – Metrics Summary

Rqmt #	Requirement	Priority	How Measured	Objective	Lower Threshold	Upper Threshold	Type	Description
1	Part Coverage Active	High	%	100	60		Perf	Total # of parts that can be reviewed using the tool - Active
2	Form, Fit Function (Form fit function interchangeable) Active	High	%	100	40		Perf	Of all the obsolete parts what is the percentage of parts that have a Form, Fit, and Function Alternative.
3	Obsolete Part Replacement Alternatives #> or = 1	High	# Alternatives	3.13	0.403		Perf	Total # of part replacement VALID alternatives ID by the tool (Different Part # from Manufacturer.) Greater then or = 1
4	Parts with no replacement	High	%	0		11.78	Perf	How well does the tool work (from a users ID)
5	Obsolescence Prediction (notification time)	High	Months	36	8		Perf	Recognize obsolescence ASAP. # Of days available to purchase a replacement part

Rqmt #	Requirement	Priority	How Measured	Objective	Lower Threshold	Upper Threshold	Type	Description
7	System Reliability (MTBF) Mean time between failures	High	Months	60	6		Perf	# Of months between Failures downtime of tool
8	Prediction Accuracy	Med	Months	1		10.66	Perf	How far off the accuracy can be in months (system said 18 months happened in 22 months)
9	Replacement Source Quantity	High	# Of sources (part)	4	0.94		Perf	# Of sources (parts) available to obtain a replacement. Same part #
1	Tool Implementation Risk	High	Complexity Factor 1-10, 1 = lowest	1		6.98	Prog	Higher complexity the more risk? Want least amount of complexity
2	Tool/ Developer Stability Ranking	Medium	Stability Rank 1-10, 10 = stable	10	5.96		Prog	Propensity of the tool vender to stay in business
3	Schedule Program Impact	High	Level of Impact 1-10, 1 = lowest	1		6	Prog	How does the Tool impact the tool (how long will it take to learn RADSS vs. doing the problem on your own)
4	Usability Factor	Medium	Factor 1 - 10, 1 = lowest	10	6.61		Prog	How well does the tool work (from a users ID)
5	Training Complexity	Med	Factor 1 - 10, 1 = lowest	1		5.95	Prog	How hard is the tool to learn
6	Training effectiveness	Med	Factor 1 - 10, 1 = bad training	10	4.98		Prog	How well does the tool work (from a users ID)
1	Initial Tool Cost divided by 5 years amortization	High	$K	18.24		595.74	TOC	Just the cost of tool (just the Software)
2	Installation Cost divided by 5 years amortization	High	$K	5		54.41	TOC	Installation of tool and licensing - turning on the first time
3	Initial Training Time	Med	Days	1		10	TOC	# Of days to be a general user
4	Recurring Maintenance & Training Cost	High	$K/Year	0		500	TOC	Reoccurring maintenance and training as software is updated

8.1.26.1 Trade Space

The trade space includes three alternatives: i2 Data without LCM, i2 Data with LCM, and Predicted i2 Data with LCM. i2 Data without LCM is the current method in use by LMMFC – Dallas and represents a subscription to the ED with some site-developed tools to access the data. The other two alternatives refer to the measured versus predicted values of the LCM tool as it was put into use at LM. The results are illustrated in Figure 8.11 which uses the metrics radar charts format to allow comparison between results. The green area is the relative benefit and the red is the relative risk.

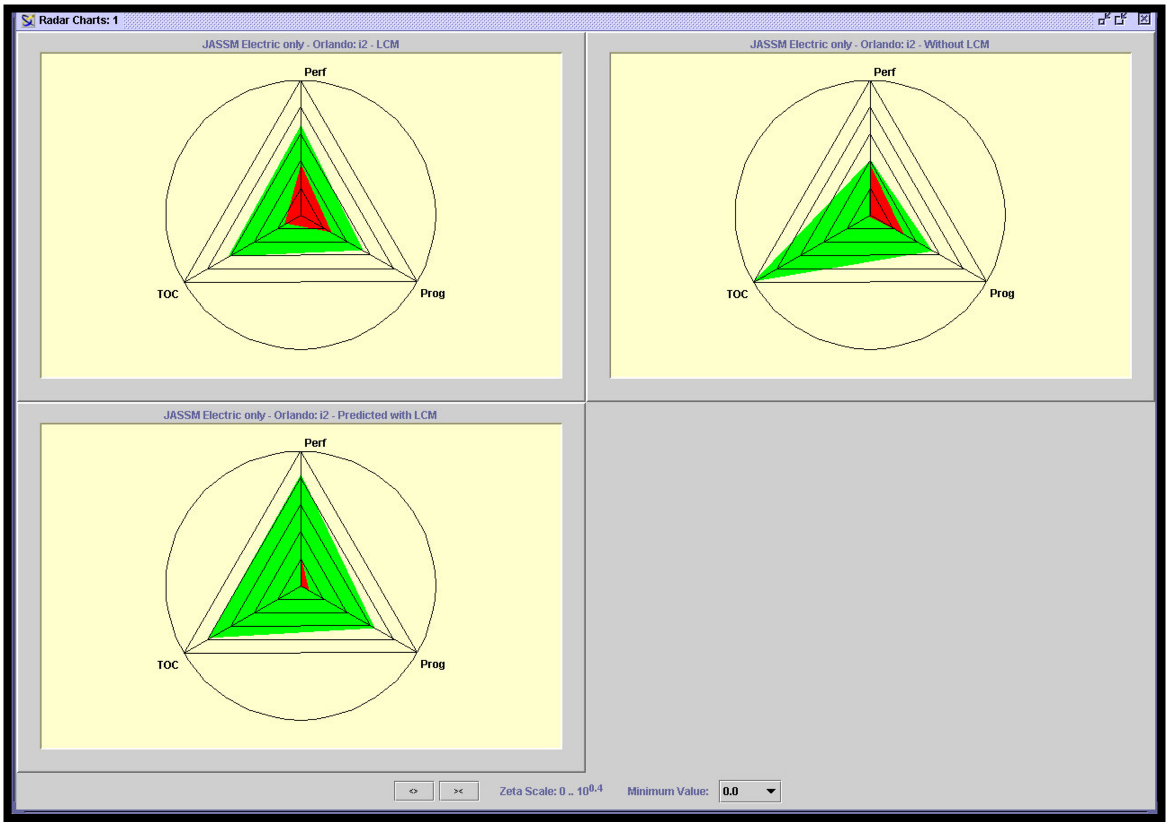


Figure 8.11 – Metrics Radar Charts

8.1.26.2 Discussion

For this model (i2 Technologies ED without the LCM) TOC is less than either the predicted, or measured, performance for a single program. However, this analysis does not take into account multiple programs using the same tool which shares the total cost and reduces the TOC for each participating program. Also, it does not take into account the cost of using the tool including running reports. When multiple programs and the cost of running reports are modeled, the TOC without LCM becomes larger than using LCM in either the test or measured cases. The cost analysis section takes the expense of running reports into account. i2 Technologies ED without LCM does not have as high performance characteristics as the LCM and therefore has a smaller effect on a program.

The analysis predicted that there would be better performance with the LCM than without. This is logical since there is greater parts coverage with the tool than without. This trade does not include savings from catching obsolescence events at the earliest stage possible.

8.1.26.3 Cost Analysis

It is imperative that some method be in place to monitor component obsolescence for assemblies that are, or could be, placed into production. Missing an obsolescence event results in an even more expensive mitigation than might be necessary than if the event were caught in a timely manner. The cost avoidance provided by early detection is not considered in the following cost analysis. The benefits of having the part numbers matched to a standardized database (i.e. part number normalization) are also not considered. Benefits of the part number normalization encompass all parts of the supply chain from design to delivery. It is difficult to determine how many parts appear in the system with incorrect part numbers and at what point in the production process these are caught.

For the purpose of this exercise the costs are divided into nonrecurring and recurring costs. Except for installation cost, the nonrecurring costs are amortized over a five-year period. This includes both Orlando and Dallas sites because of the combined licensing agreement with i2 Technologies. The following tables do not have the installation cost associated with the first year amortized over the amortization periods chosen.

This cost analysis assumes that there are around 50 individual configurations with around 10 parts lists each that contain electronic active components. This count of 500 parts lists is intended as a conservative estimate of the number of parts lists that need to be monitored for obsolescence. This analysis assumes that configuration data for the each BOM in the ED case must be scrubbed in order to obtain accurate lifecycle data. This accounts for the 5 hours to run a report without the new system versus the 1 hour it would take with the new system. Not including the amortization, the costs for the first year are as follows (Table 8.5):

Table 8.5 – ED/SRM Cost Analysis Summary

		ED		SRM
Tool Costs		$ -		$ 1,000,000
Subscription Cost		$100,000		$100,000
Installation Cost				$250,000
Maintenance:				
Cost		$400,000		$275,000
Training:		$20,000		$140,000
Run Reports:				
Bills of Materials	500		500	
Times / Year	4		2	
Hours Report	5		1	
		$1,000,000		$100,000
Examine Reports:				
Hours Report	1		1	
Total Examination		$200,000		$100,000
First Year :		$ 1,700,000		$ 1,965,000

Amortizing all the costs, with the exception of the installation cost, over 5 years ,with an assumption that there are 500 BOMs to evaluate, spreads the cost such that the there is a positive difference with the usage of the new SRM system in the first year of $555K. Over the five year period the savings would be 4.2 million dollars. This is illustrated in the following table (Table 8.6):

Table 8.6 – ED/SRM Cost Analysis Details

Payoff Years	5	Eng. Rate	$100	BOMs	500

	Year	1	2	3	4	5	6
ED	Tool Cost	$0	$0	$0	$0	$0	$0
	Maintenance	$400,000	$400,000	$400,000	$400,000	$400,000	$400,000
	Subscription	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000
	Reporting	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000
	Training	$20,000	$20,000	$20,000	$20,000	$20,000	$20,000
	Total:	$1,720,000	$1,720,000	$1,720,000	$1,720,000	$1,720,000	$1,720,000
	Running Total:	$1,720,000	$3,440,000	$5,160,000	$6,880,000	$8,600,000	$10,320,000
SRM	Tool Cost	$200,000	$200,000	$200,000	$200,000	$200,000	$0
	Maintenance	$275,000	$275,000	$275,000	$275,000	$275,000	$275,000
	Subscription	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000
	Reporting	$200,000	$200,000	$200,000	$200,000	$200,000	$200,000
	Training	$140,000	$20,000	$20,000	$20,000	$20,000	$20,000
	Installation	$250,000					
	Total:	$1,165,000	$795,000	$795,000	$795,000	$795,000	$595,000
	RunningTotal:	$1,165,000	$1,960,000	$2,755,000	$3,550,000	$4,345,000	$4,940,000
	Difference	$555,000	$1,480,000	$2,405,000	$3,330,000	$4,255,000	$5,380,000

Accelerating the amortization schedule to three years and keeping the number of BOMs (500) constant changes the initial first year payoff to $421K (Table 8.7)

Table 8.7 – ED/SRM Cost Analysis Details

Payoff Years	3	Eng. Rate	$100	BOMs	500

	Year	1	2	3	4	5	6
ED	Tool Cost	$0	$0	$0	$0	$0	$0
	Maintenance	$400,000	$400,000	$400,000	$400,000	$400,000	$400,000
	Subscription	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000
	Reporting	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000	$1,200,000
	Training	$20,000	$20,000	$20,000	$20,000	$20,000	$20,000
	Total:	$1,720,000	$1,720,000	$1,720,000	$1,720,000	$1,720,000	$1,720,000
	Running Total:	$1,720,000	$3,440,000	$5,160,000	$6,880,000	$8,600,000	$10,320,000
SRM	Tool Cost	$333,333	$333,333	$333,333	$0	$0	$0
	Maintenance	$275,000	$275,000	$275,000	$275,000	$275,000	$275,000
	Subscription	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000
	Reporting	$200,000	$200,000	$200,000	$200,000	$200,000	$200,000
	Training	$140,000	$20,000	$20,000	$20,000	$20,000	$20,000
	Installation	$250,000					
	Total:	$1,298,333	$928,333	$928,333	$595,000	$595,000	$595,000
	RunningTotal:	$1,298,333	$2,226,667	$3,155,000	$3,750,000	$4,345,000	$4,940,000
	Difference	$421,667	$1,213,333	$2,005,000	$3,130,000	$4,255,000	$5,380,000

Reducing the number of monitored BOMS to a more modest 400 and amortizing over 5 years returns the following table (Table 8.8):

Table 8.8 – ED/SRM Cost Analysis Details

Payoff Years	5	Eng. Rate	$100	BOMs	400

	Year	1	2	3	4	5	6
ED	Tool Cost	$0	$0	$0	$0	$0	$0
	Maintenance	$400,000	$400,000	$400,000	$400,000	$400,000	$400,000
	Subscription	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000
	Reporting	$960,000	$960,000	$960,000	$960,000	$960,000	$960,000
	Training	$20,000	$20,000	$20,000	$20,000	$20,000	$20,000
	Total:	$1,480,000	$1,480,000	$1,480,000	$1,480,000	$1,480,000	$1,480,000
	Running Total:	$1,480,000	$2,960,000	$4,440,000	$5,920,000	$7,400,000	$8,880,000
SRM	Tool Cost	$200,000	$200,000	$200,000	$200,000	$200,000	$0
	Maintenance	$275,000	$275,000	$275,000	$275,000	$275,000	$275,000
	Subscription	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000
	Reporting	$160,000	$160,000	$160,000	$160,000	$160,000	$160,000
	Training	$140,000	$20,000	$20,000	$20,000	$20,000	$20,000
	Installation	$250,000					
	Total:	$1,125,000	$755,000	$755,000	$755,000	$755,000	$555,000
	RunningTotal:	$1,125,000	$1,880,000	$2,635,000	$3,390,000	$4,145,000	$4,700,000
	Difference	$355,000	$1,080,000	$1,805,000	$2,530,000	$3,255,000	$4,180,000

Finally, the break even number of BOMs in this analysis over the 5-year period is 75 as show in Table 8.9.

Table 8.9 – ED/SRM Cost Analysis Details

Payoff Years	5	Eng. Rate	$100	BOMs	75

	Year	1	2	3	4	5	6
ED	Tool Cost	$0	$0	$0	$0	$0	$0
	Maintenance	$400,000	$400,000	$400,000	$400,000	$400,000	$400,000
	Subscription	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000
	Reporting	$180,000	$180,000	$180,000	$180,000	$180,000	$180,000
	Training	$20,000	$20,000	$20,000	$20,000	$20,000	$20,000
	Total:	$700,000	$700,000	$700,000	$700,000	$700,000	$700,000
	Running Total:	$700,000	$1,400,000	$2,100,000	$2,800,000	$3,500,000	$4,200,000
SRM	Tool Cost	$200,000	$200,000	$200,000	$200,000	$200,000	$0
	Maintenance	$275,000	$275,000	$275,000	$275,000	$275,000	$275,000
	Subscription	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000
	Reporting	$30,000	$30,000	$30,000	$30,000	$30,000	$30,000
	Training	$140,000	$20,000	$20,000	$20,000	$20,000	$20,000
	Installation	$250,000					
	Total:	$995,000	$625,000	$625,000	$625,000	$625,000	$425,000
	RunningTotal:	$995,000	$1,620,000	$2,245,000	$2,870,000	$3,495,000	$3,920,000
	Difference	($295,000)	($220,000)	($145,000)	($70,000)	$5,000	$280,000

However, it can be seen that, even with break even point of 75 BOMs reviewed a year, this is extremely conservative. A more likely number would be 75 BOMs every 3-6 months, and more likely higher as users discover the ease of performing evaluations and its utility in reporting to supervision.

8.1.27 Recommendations

Regardless of the tool or technology employed, it is vital that a systematic controlled process be used to manage the component information of every company and program. The solution should be tightly integrated with design, purchasing and production tools. i2 Technologies' SRM suite can be used to implement this technology at a cost.

8.1.27.1 Part Number Normalization

There must be in the data management plan a process to match user part numbers with known good part numbers in order to reduce data entry errors. While providing a one to one correspondence with life cycle records, it can also simplify the processes involved with checking, procurement, receiving and quality by having those known good part number. It can prevent unnecessary charges when changes to documentation are required to correct an incorrect part number.

8.1.27.2 Life Cycle Monitoring

The life cycle status of each and every single component should be monitored and reported as often as possible, except in rare circumstances loading a BOM into a predictive tool every week in cost prohibitive or when the component is relatively insensitive to abrupt changes (e.g. fasteners, etc). If the BOM exists in a user database such as the SRM tool then it is possible to call up the LCM tool and see the life cycle data for all the parts in the BOM. Using the automatic alerts the LCM tool can monitor all the components of the various BOMs and automatically alert users of necessary changes.

8.1.27.3 Obsolescence Management / Mitigation

Efforts to reduce the cost associated with obsolescence necessitate the identification of issues as early as possible. The greater the lead time the greater the cost avoidance.

8.1.27.4 Risk

There are three known categories of risks for this tool those being: technological, organizational, and business. Technological risks here are categorized as those circumstances that arise from the tool itself. Organizational risks encompass non-technical human factors from the corporate standpoint. Business risks involve those risks derived from doing business with i2 Technologies.

8.1.27.5 Technology

The technological risks come from two sources: implementation of the software, and accuracy of the tool. The tool can be highly integrated with existing supply chain infrastructure, which creates a degree of risk associated with this installation and integration. SRM provides a tool, called webMethods, which facilitates these interfaces by providing a library of standard interfaces with leading toolsets and software programs. It also allows users to develop their own unique interfaces as needed.

The life cycle content relies on i2 Technologies' proprietary algorithm for which they provide no reports as to the accuracy of the predictions. As noted previously, some items went from being near the end of life to having several more years of production. Also, a few items declined faster than the algorithm predicted. Aside from continually contacting each vendor for information regarding the proposed life cycle of each part, there is no sure method of ascertaining the life cycle of a particular component. However, predicting at least provides a logical approach to determining the YTEOL dates that can be modeled, validated against empirical data, and refined. This can be reduced only by tracking and proving SRM's capability and tracking its performance.

8.1.27.6 Organization

The main organizational risks come from program and departmental buy-in. Buy-in is required from both the bottom-up and top-down in order to accomplish the successful utilization of the tools. Components Engineering and participating programs need sponsorship from management in order to have the use of the tools accepted and encouraged. Cost savings arguments should be used to assist in accomplishing these objectives. These should include savings items such as the reduced time to run life cycle reports, and the identification of obsolescence issues earlier in the life cycle. Without buy-in from the top, standardization and utilization synergistic effects will not occur. Users need to be included as much as possible in the optimization and customization of the tools. They should receive the necessary training to understand and fully employ the tool.

Organizational risks can also be minimized though the use of standardized procedures and processes. SRM also supports this reduction by providing users with, and ensuring compliance to, common workflows.

8.1.27.7 Business

These risks must be very well understood since i2 has struggled significantly since the Technology Boom bust of 2000-2001. i2 Technologies during the past few years has had serious financial difficulties. While it has a large cash reserve it had been burning the cash at a rate that concerned investors. i2's stock price dropped from over $60 a share to where they were actually de-listed from the stock exchange in 2003 due to financial reporting adjustment improprieties. They agreed to a $10M, no-fault penalty reimbursement to their stockholders to resolve the issue. Their stock price had dropped to ~$1 by 2004 but had over $400M is sales for 2003. It is now traded on the over the counter (OTC) market. Most of their support has been shifted offshore to India which this places another layer of risk along with potentially adding Defense Federal Acquisition Regulation (DFAR) and national security issues.

8.1.28 Conclusions

A large suite of software had to be installed temporarily at the LMMFC-O facility in order to test the tool including both the software suite and a fair amount of middleware, as well as installation of the ED. Several of the parts changed life cycle state during the study, moving both up and down in status. These changes were used by the JASSM Components Engineering team to make decisions concerning their parts management. The JASSM team found the information useful and was able to make decisions based on the knowledge provided by the tool.

The LCM tool can be a useful addition to a Components Engineering team's components management program. The tool does not present a cost effective solution for a single program due to the bundling of the supply chain management tools with the LCM. However, for a company or corporate wide solution SRM with LCM can be a powerful tool for managing component data. The automatic alerts provide an automatic means to inform the users of the components of the possibility of a problem. The break-even point for BOM monitoring is relatively low for a tool of this size; however, it is unlikely that a single program would be able or willing to bear the expense of such a tool.

8.2 RADSS 2000 / LANTIRN Pilot

Northrop Grumman IT's (NGIT) RADSS 2000 Decision optimization software tool was applied to the LANTIRN program to determine if it could enable users to make more educated obsolescence management decisions with an optimized decision model. The 12-month pilot focused on providing faster and more accurate obsolescence solutions, development of a common usable flow model and tool for access, a more simplified solution process, and usage by untrained or inexperienced personnel. The expected benefits included: more accurate obsolescence solutions, earlier solution identification, increased obsolescence awareness, greater analysis, and increased alternatives, reduced risk, and reduced cost through a common, automated process.

The Resource Allocation Decision Support System (RADSS) by NGIT is a Windows-based decision support system which assists program management budget resources. The tool's primary purpose is to aid the user in making financial management or investment decisions. It can be applied to a range of situations such as technology investments, environmental cleanup, portfolio planning, or any similar scenario in which the decision maker has dozens, hundreds, or thousands of choices and limited or constrained resources. Uses include decision support for programming, budgeting, logistics support, technology investment, environmental cleanup, and cost-benefit analysis. Northrop Grumman asserts that RADSS is a unique and powerful decision tool, limited only by the imagination and creativity of the user. The tool is designed primarily for managers, responsible for the budgeting or allocation of financial or manpower resources, and allows them to deal with a large number of requirements and limited resources. It is intended to help them improve prioritization and achieve greater benefits during planning, programming, or budgeting exercises including budget reductions. RADSS is useful in tracking resource allocations for a large number of applications including scenario analysis, budget cut exercises, and sensitivity analysis. The tool is a stand-alone system that can import data from external databases. It includes a series of standard reports, an MS Access relational database that provides powerful tailoring, and query capabilities. Best results are achieved when RADSS is used as an integral part of a structured decision process.

8.2.1 <u>RADSS Pilot – Background:</u>

The RADSS pilot involved the Lockheed Martin Corporation (LMC) (Missiles and Fire Control - Orlando and Dallas, and Aeronautics - Ft. Worth) in conjunction with what was then Litton TASC, now Northrop Grumman Information Technology.

This pilot assessed Northrop Grumman's Resource Allocation Decision Support System optimization software. The RADSS Pilot and Parts Obsolescence Decision Model (PODM) were approved following the POMTT Yearend review in December 2001. RADSS was applied to the LANTIRN program to attempt to support and perform "low level" obsolescence management.

LANTIRN was chosen as the pilot test program because of its long-term production requirements, its ten-year production history, and its experienced DMSMS program personnel. LANTIRN has a consistent 10 years knowledge base of obsolescence management and decision-making. Lockheed Martin was able to use the existing LANTIRN obsolescence flow model as a strawman for further model development. The LANTIRN Component Obsolescence Management Database (COMAND) database was also used to compare the pilot solutions to already developed solutions. LMMFC–O has a resident Subject Matter Expert (SME) expert in Carolynn Amberntson and Brian McMullen from Missiles and Fire Control Dallas participated as Dallas' SME.

LMMFC-O also supports development of manageable and usable obsolescence tools. The RADSS pilot users' expected the software to increase savings through a combination of reduced labor cost and a common, optimized practice. The RADSS Pilot users also expected an increase in the lead-time to identify potential obsolescence problems. The pilot team attempted to demonstrate that it is feasible to reduce obsolescence decision time by using a single methodology and distribute it company wide.

8.2.1.1 <u>What was involved?</u>

The pilot involved training, model creation, model implementation, and final evaluation. Training was broken down into three sessions. During the first session the team concentrated on identifying a model to use in the RADSS software. The second session involved conceptualizing this model and starting the data collection. For the final phase the model was imported into RADSS.

LMMFC-O developed two different decision approaches during the evaluation of the RADSS software. The pilot team first developed the Complex Part Model with the use of the two Subject Matter Experts (SMEs). This model would be developed to use in the RADSS software and would assist engineers with complex obsolescence decisions. This model also served as a basis for the second Obsolescence Decision Tool (ODT) model that was designed to help engineers with simple solutions. The ODT tool will be discussed in later sections.

The only software needed for this pilot was the RADSS software which was provided by NGIT through a no-cost license and required Microsoft® Access 97 (or higher). In order to test and evaluate the software and models the pilot team would need a combination of: two program technical SMEs, one POMTT lead for model development and data input, one software programmer, one member of program management, and one tool SME. The logistics and analysis of the pilot were straightforward but the overall question was: Could a pilot team conceive and implement a useable and versatile model that would provide a desirable decision making process? The analysis would use the two SMEs to review the answers of the model against their own obsolescence decision experience.

8.2.2 RADSS Pilot Introduction

This section focuses on the RADSS software and its performance with the IRST model that the pilot team developed.

RADSS was applied to the LANTIRN/IRST (Low Altitude Navigation and Targeting Infrared for Night / Infrared Search and Track) system to help users make more educated obsolescence management decisions by applying a predefined and optimized decision model.

There were several reasons why the RADSS 2000 and IRST (LANTIRN) combination was selected for development of the obsolescence decision model. Resident experts already existed and it was felt that their experience and knowledge in this area could be completely documented. These Subject Matter Experts (SMEs) have numerous years of obsolescence experience on production programs. The LANTIRN program was chosen because it has been actively managing obsolescence for over ten years. Another reason was the relatively limited number of obsolescence experts and their availability. The greatest reason for the pilot was the increasing use of commercial components on new programs and the resulting increase in obsolescence cases. Therefore, the pilot focused on providing faster and more accurate obsolescence solutions through the development and use of a common flow model.

8.2.3 RADSS Training

Training classes were held to assist in the development of a concept, and creation and operation of the decision model.

8.2.3.1 RADSS Training Session 1

The first training class was a brainstorming session to develop a model concept. Three proposed model solutions were developed those being a Low-Level model, Aging Aircraft Avionics Methodology model and the Strategic Roadmap model. After evaluation, it was decided to focus on the Low-Level Model.

8.2.3.1.1 Low-Level Model Development Approach

Orlando and Dallas technical specialists would work together to build a more detailed model (template) for low-level, complex, obsolescence decisions that are as generic as possible, while allowing for on high-cost obsolescence alternatives such as redesign, GEM'ing, and die banking where the circumstances warrant. The decision criteria and flowcharts were to be expanded to include tradeoff and cost benefit criteria. The team would then populate the model with the data collected from the LANTIRN/IRST program, run the analysis, and review the results. Of particular interest was to see if the template could be applied to other obsolescence cases, regardless of the part or program, without significant modification being required.

8.2.3.3 RADSS Training Session 2

The second RADSS training session was used to provide additional analysis of the models and served as an introduction to the RADSS tool. The tool training consisted of

- Database Structure
- Initial Setup
- Establishing Decision models
- Creating Problem Sets
- Creating Problems
- Creating Scenarios
- Constraints
- Rules
- Running Scenarios
- Producing Reports

8.2.4 RADSS Training Session 3

For the third training session the team developed and populated a training model using an Excel based spreadsheet which would be imported into RADSS. This advanced training consisted of

- Importing Data
- Exporting Data
- Problems and Scenarios
- Data base queries
- Running Scenarios

Evaluating Results

8.2.5 RADSS/IRST (LANTIRN) Pilot summary

The RADSS Graphical User Interface (GUI) software and licenses were installed and established on a development server. Complete testing was performed on the software and the decision process and then the pilot team (both experienced and inexperienced personnel) began using the software to evaluate its potential for use with the day-to-day obsolescence issues on the program. The team looked for the best complex obsolescence decision model for the given program. Analysis of the model continued through the life of the pilot to ensure that it returns timely, valid and reliable decisions.

Figure 8.12 shows the relationship of the pilot's elements and the use of the web as the backbone for access and data transmission. The combination of the Obsolescence Flow Model, the RADSS Tool, and the Decision template comprise the Obsolescence Decision Tool.

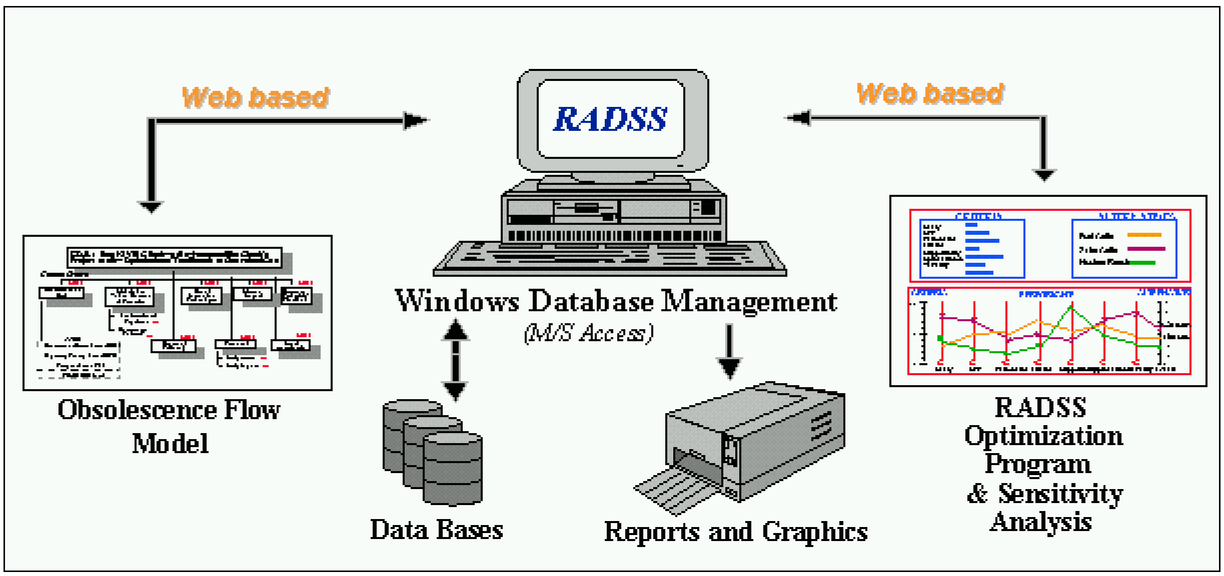


Figure 8.12 – Obsolescence Decision Tool

8.2.6 Problem Set

The first step in the pilot was to develop a problem set for the RADSS software. The pilot team chose a redesign effort for the LANTIRN program that involved a single part that was going obsolete. The model would capture all of the potential solutions and actions the program could perform to mitigate the effects (Figure 8.13 is a screen capture of the problem set in RADSS).

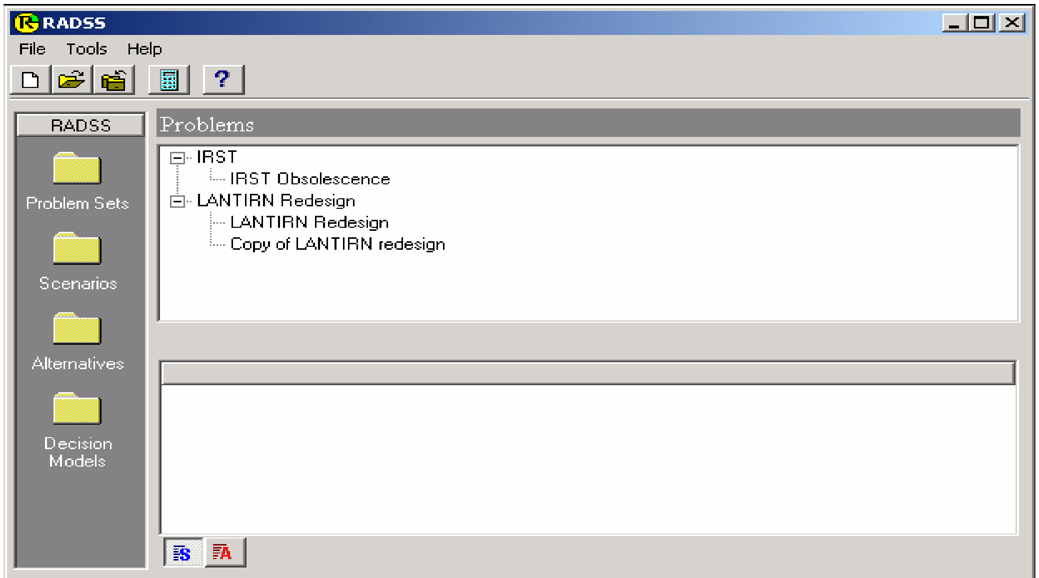


Figure 8.13 – RADSS 2000 Tool

8.2.7 Template

A problem set was defined to allow the team to create a template which could be imported into RADSS. The template was made using Microsoft Excel and the resulting spreadsheet was then imported into the RADSS database. The template includes all the potential decision criteria involved in the problem set. The resulting template therefore included all the potential decision (replacement, rework, and redesign) alternatives (Figure 8.14).

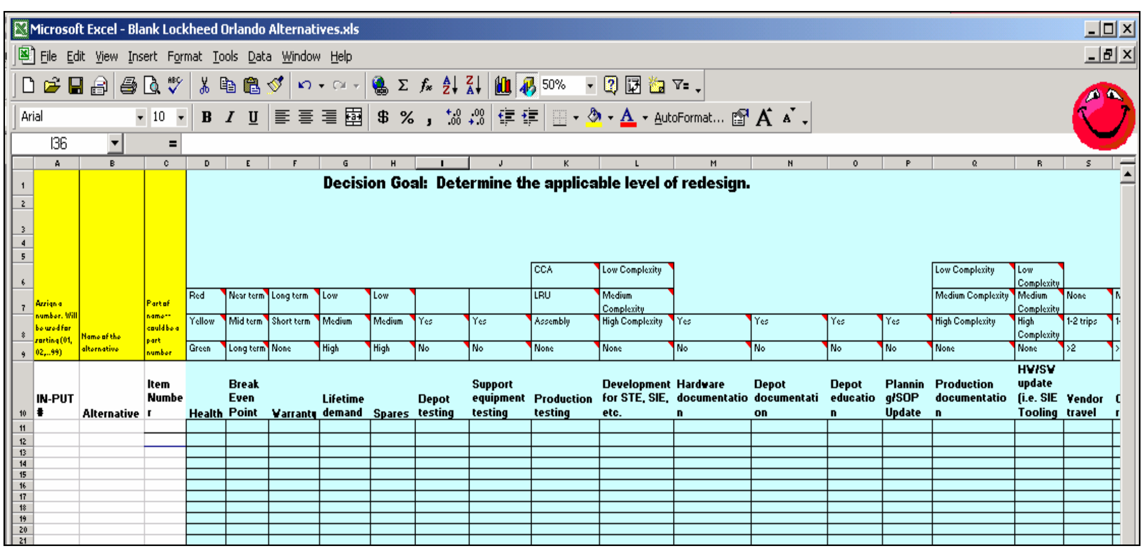


Figure 8.14 – RADSS 2000 Decision Template

8.2.8 Decision Weighting

Decision weighting was done through a separate COTS software package called Expert Choice, which was used to develop pair-wise comparisons of the design criteria. These results were then manually imported into RADSS. The team applied a weight to all the criteria developed in the template. It then placed percentages of importance on each individual criteria and sub criteria. This rendered the pair-wise comparison (Figure 8.15).

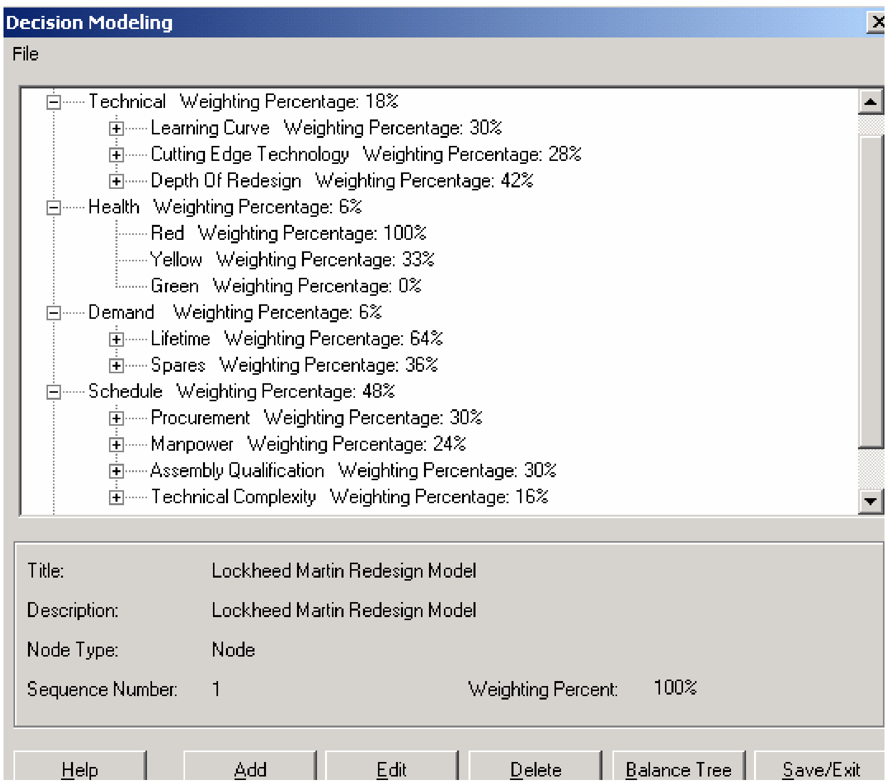


Figure 8.15 – Importance Percentage Weightings

8.2.9 Alternatives

The alternatives are the available "solutions" to the problem set. Shown below is the populated RADSS database with all the potential redesign solutions that could result from this problem set. For this single part redesign problem the pilot team developed over 90 possible alternatives (Figure 8.16). Alternatives ranged from last time buy to part replacement, card replacement, system replacement and others.

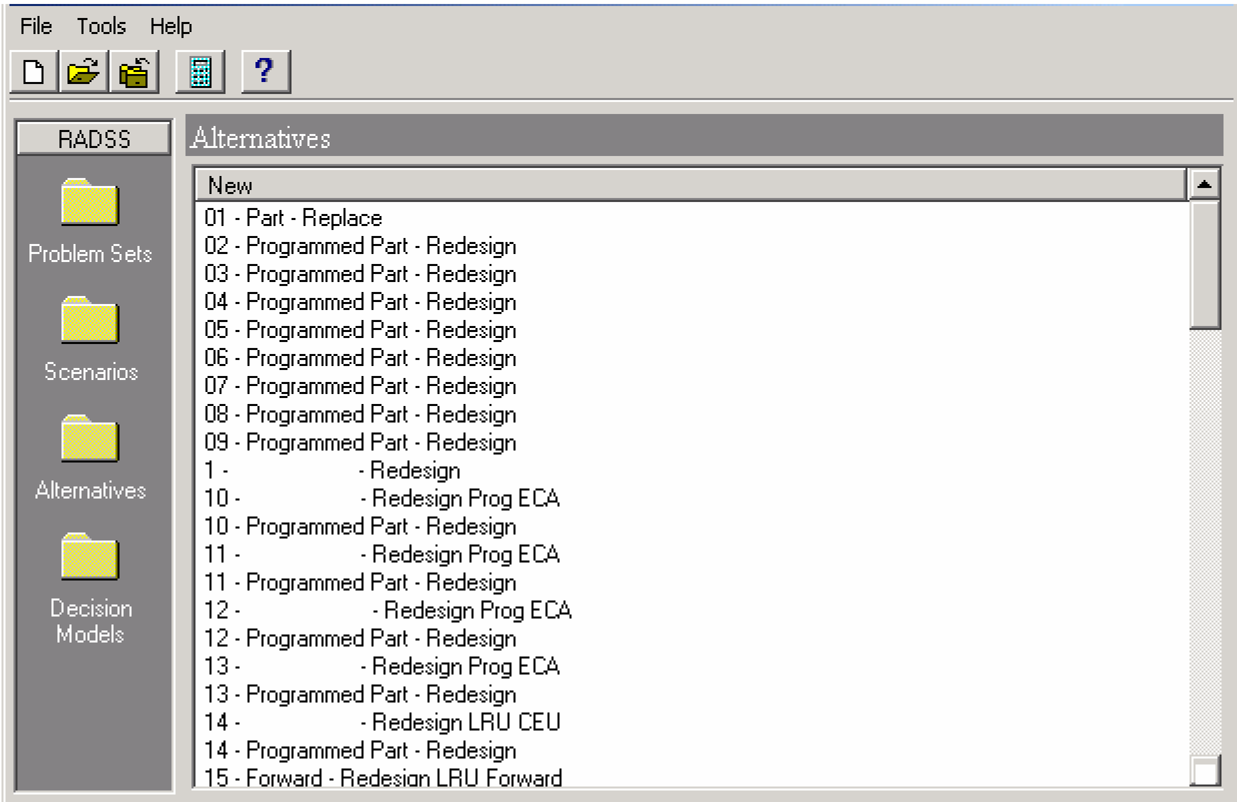


Figure 8.16 – Decision Alternatives

8.2.10 <u>Rules</u>

Rules had to be developed in the RADSS system so that the solution does not include multiple alternatives that cannot be combined, or a solution that is mutually exclusive or too costly. For example, program management would not want a solution to tell them that it is necessary to redesign a specific card *and* each individual part on the card. In the redesign pilot, the team had to develop over 300 rules to encompass 90 plus alternates (Figure 8.17).

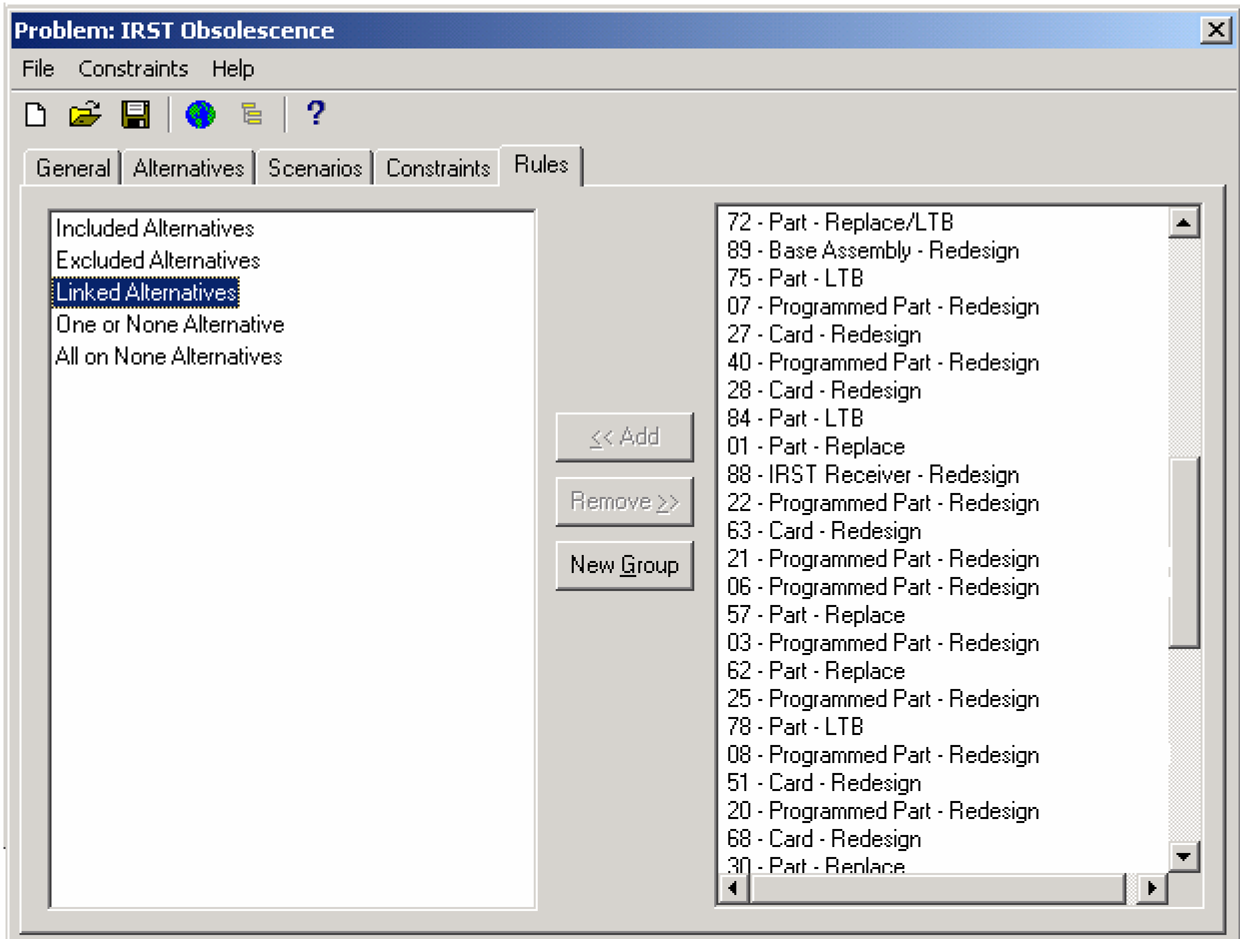


Figure 8.17 – Decision Alternatives

8.2.11 <u>Score Card</u>

The Score Card is then generated by the RADSS software and includes all possible combinations of alternatives with a numerical score ranked by the highest to the lowest. It also provides the user with a true/false reading as to whether the possible solution is feasible, and it optimizes the alternatives to give a discrete benefit and cost score (pulled from the template developed earlier), and a combined benefit/cost score. The highest benefit/cost score feasible is then considered the optimal solution. The obsolescence model for the LANTIRN decision returned solution that said a Last Time Buy was the most optimal for that particular event. (Figure 8.18)

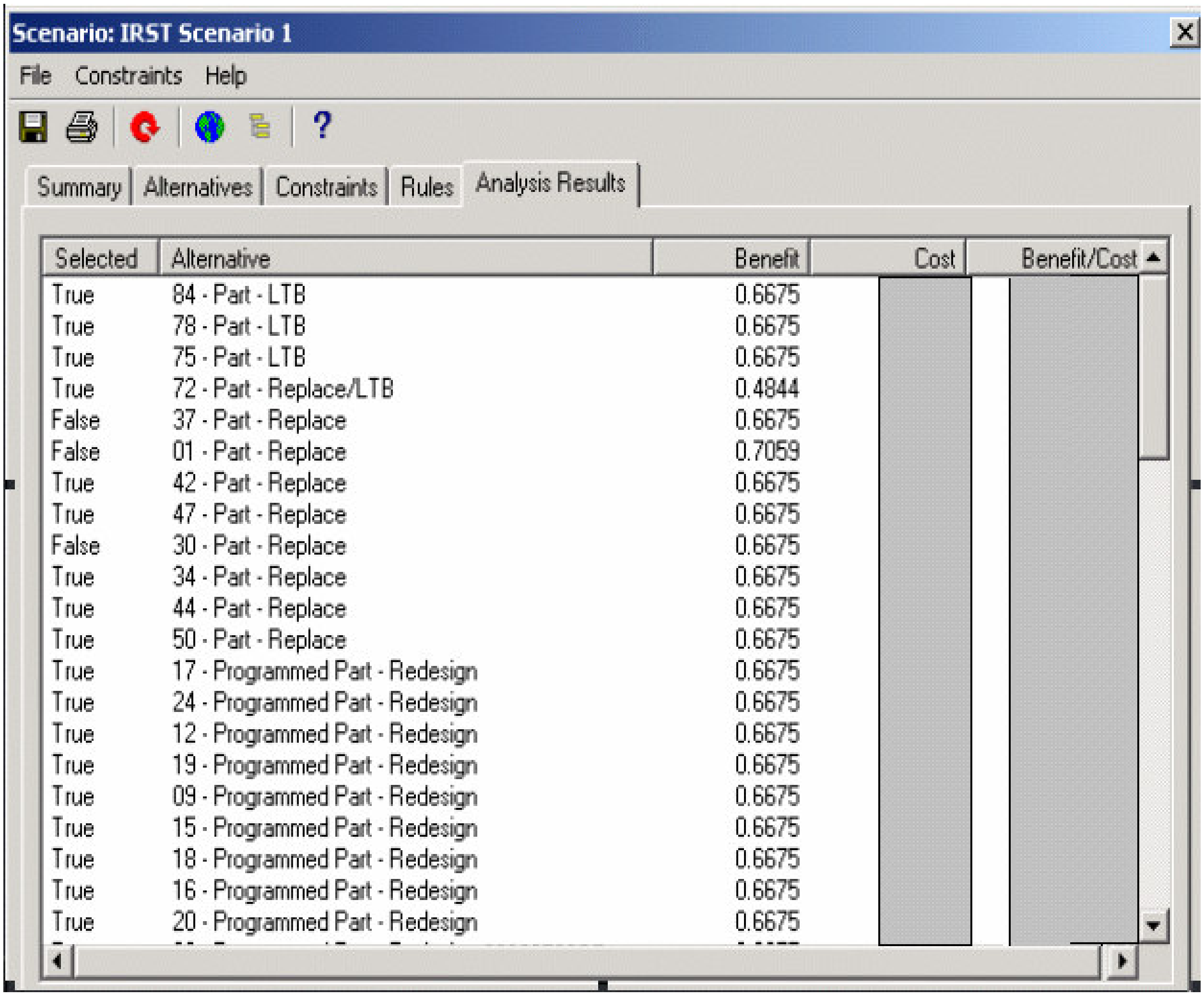


Figure 8.18 – RADSS 2000 Score Card

8.2.12 <u>RADSS Model Pilot Results</u>

In conclusion, the pilot team had a number of findings concerning the RADSS software evaluation. The tool is powerful because it can accept multiple decision points at multiple levels. However, there is a significant learning curve before one can use the software. For example, the 3 training sessions and model development for just the one LANTIRN problem took approximately 6 months of time, and at least two weeks of total manpower effort on just the specific model.

The tool also requires considerable data population for the RADSS template development. Even after a user has been trained on its use, the tool requires that the user be fairly advanced in its use in order to understand and evaluate the results.

RADSS requires funding and time for substantial software, installation and training and this can result in a significant cost, especially for non-recurring costs due to the uniqueness of each problem set. In order to use the tool, the program's schedule must allow sufficient time for each decision (data collection, input, configuration and analysis) to be performed.

The final results were that, although RADSS can provide a logical, quantitative approach to critical as well as day-to-day decisions containing multiple alternatives, it is too powerful and complex to use to solve the simpler, everyday decisions. Therefore, at the completion of the assessment of the RADSS 2000 software the pilot team began to explore the concept of an Obsolescence Decision Tool using the model (Figure 8.19) and experience gained from the pilot.

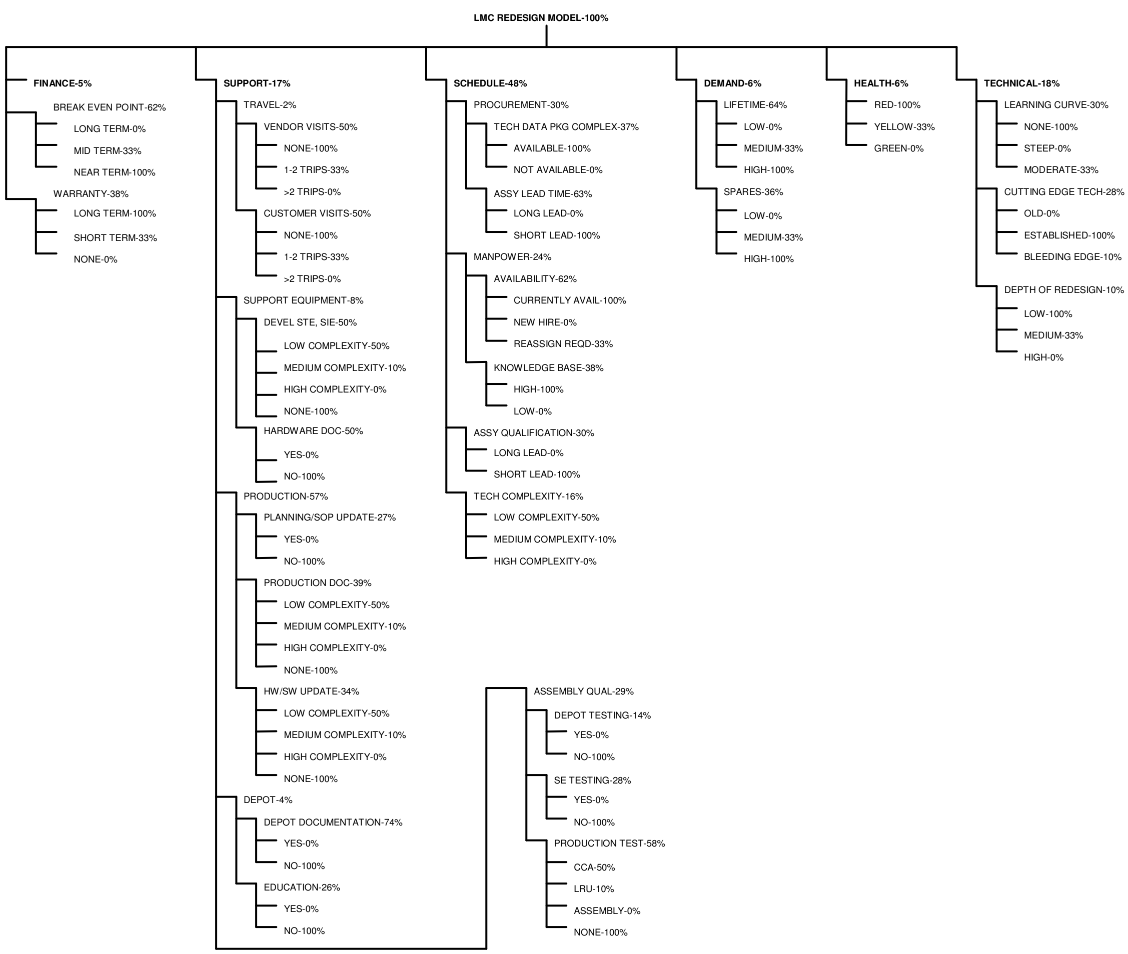


Figure 8.19 – LM Redesign RADSS Model

8.2.13 ODT Overview

The evaluation of RADSS raised concerns with LMMFC-O's current obsolescence decision processes. The team knew that no common process existed for lower level solutions across programs and that no commercially available decision support software existed to help with these day-to-day obsolescence problems. Also it was found that, to in order to use the RADSS tool in this effort, the mitigation of DMS would require considerable training and expertise. The pilot team felt the need to address these needs with an obsolescence process that would help to quickly solve common obsolescence problems and ensure that non-obsolescence trained engineers could be educated in obsolescence management. Thus the idea of the ODT (Obsolescence Decision Tool) software was born.

8.2.14 The Flow Model

As part of the RADSS Pilot, the team initially decided to review and capture the one existing internal obsolescence process, which then consisted of a one-page overview, and then the SMEs proceeded to document their existing decision process and activities. This provided a much more detailed flow model with over 360 discrete decision points in a hierarchy of problem solutions ranging from the cheapest / simplest solution to the hardest, most complex / costly solution. These solutions included but were not limited to (See also Figure 8.20):

External and internal stock
Replacements and Alternates (F^3I)
Aftermarket suppliers
Evaluation of CCU and LRU
Reverse Engineering
VHDL
GEM-ability
Die reclamation

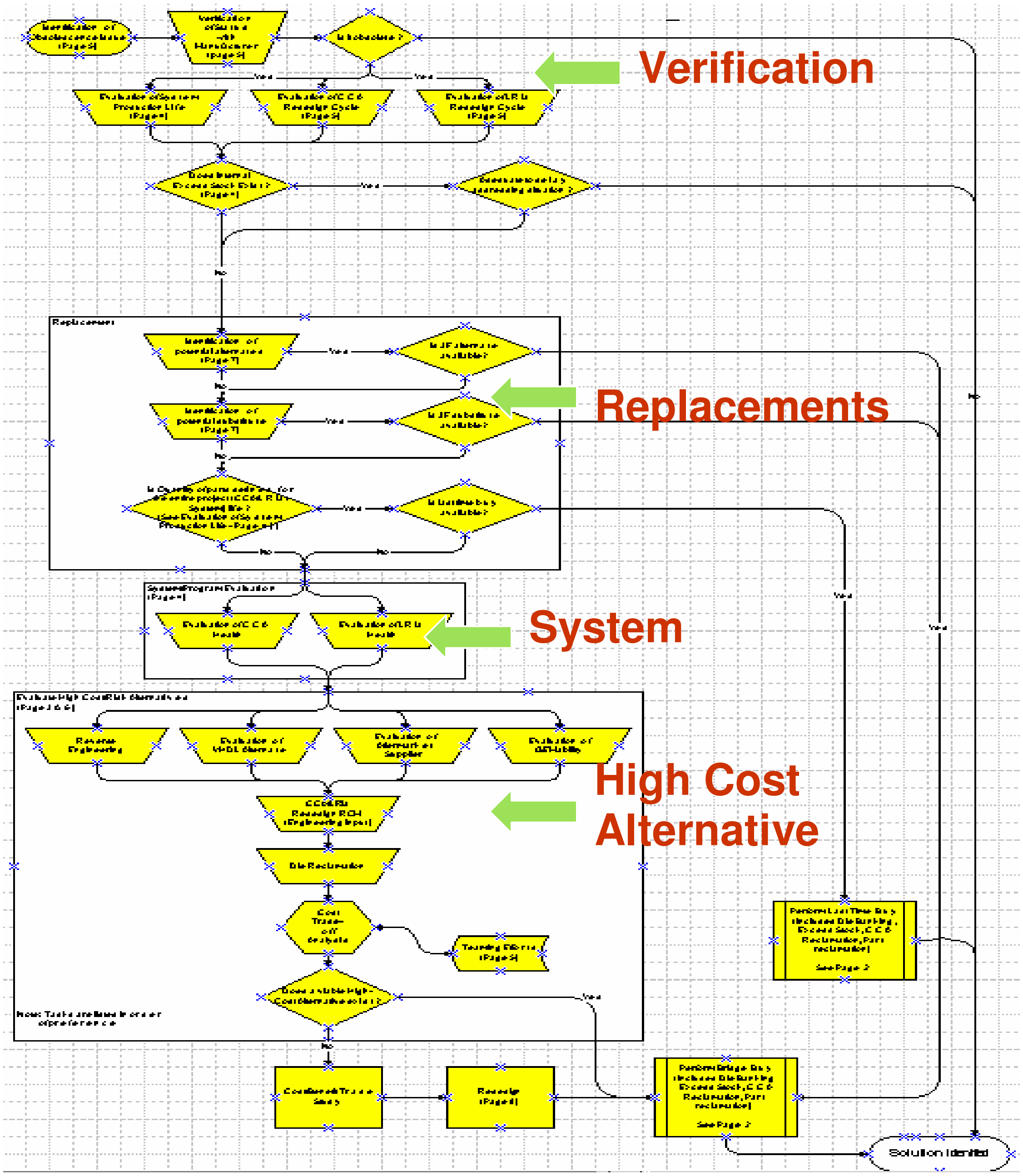


Figure 8.20 – ODT Flow Model

Within each one of the flow model sub-systems (Verification, Replacements, System Evaluation, and high cost alternatives) is a detailed decision hierarchy that can lead to a potential solution.

8.2.15 Creating ODT

As the flow model developed the team also recognized the need to provide a user-friendly interface that was easy to use, easy to follow, and would support self-documentation. The team evaluated the completed model and transferred it to Microsoft's .NET Java Code for implementation on a server and connection to the LMMFC intranet. A database was then established to track the system's users and the information about each particular problem. Finally, links to outside resources were added for external websites to provide a more complete set of solutions and resources.

8.2.16 ODT Description

On the initial home page the tool ask users to login using their company Login ID. Once the user is logged-in, the tool captures their name, phone number, e-mail address, program information and other pertinent information. This is stored in the Microsoft Access database to provide metrics and track who is using the software and the program they are working. (Figure 8.21)

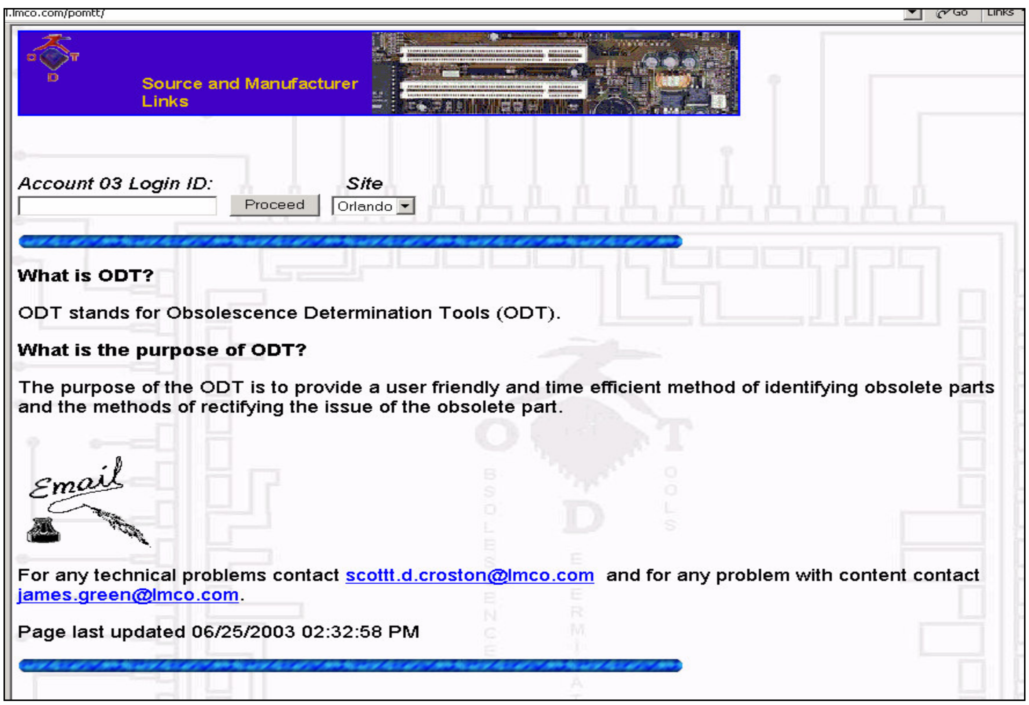


Figure 8.21 – ODT Logon Screen

8.2.17 Part Name/Number and Previous Session

As part of the database construction, the ODT captures the users' part name and number to eliminate dual efforts. The ODT uses this information to help identify solutions that were previously worked and the contact information of the engineer who worked the problem. The database also tracks the time each engineer spends on each question, category and solution to monitor their progress and the performance of the tool.

The software also tracks all the answered questions so that the user can leave the program and work other issues as needed. The user can also hold multiple sessions open if needed (Figure 8.22).

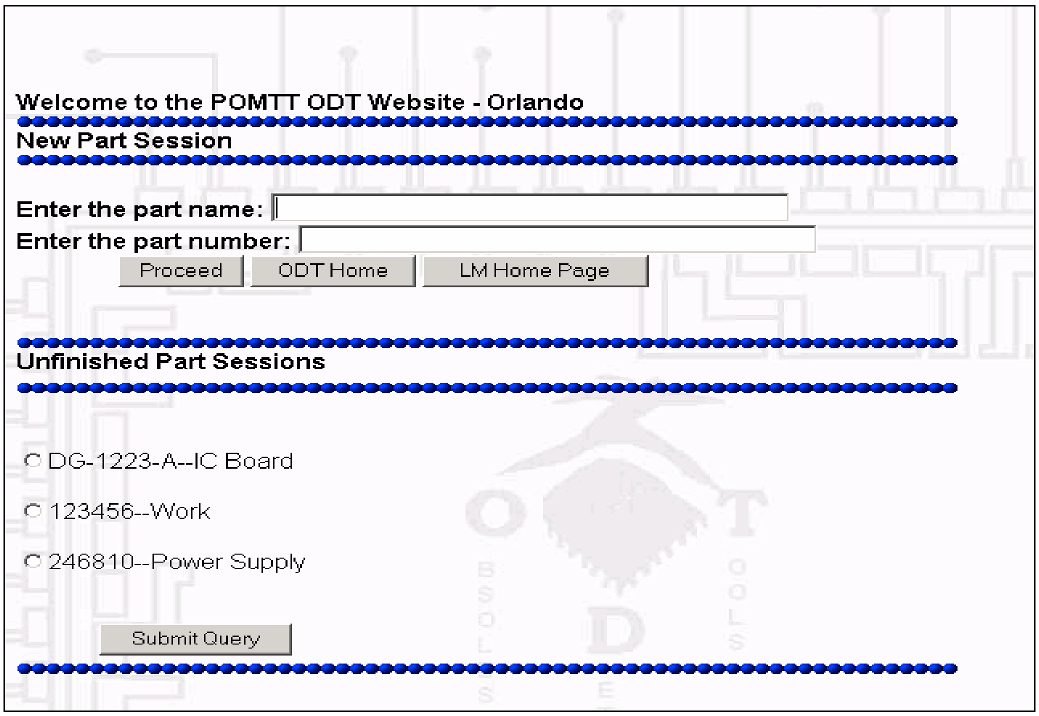


Figure 8.22 – ODT Initial Data Entry Screen

8.2.18 <u>Other Data Capture</u>

The software also captures other data throughout the solution process. ODT will ask for descriptions on certain questions so that the tool can provide a documented final report with all the questions asked, the answers provided, and (especially) the reasoning behind them. This provides both a hard copy and an electronic copy of the decision process and reasoning that can be very useful when justifying and recommending decisions to management (Figure 8.23).

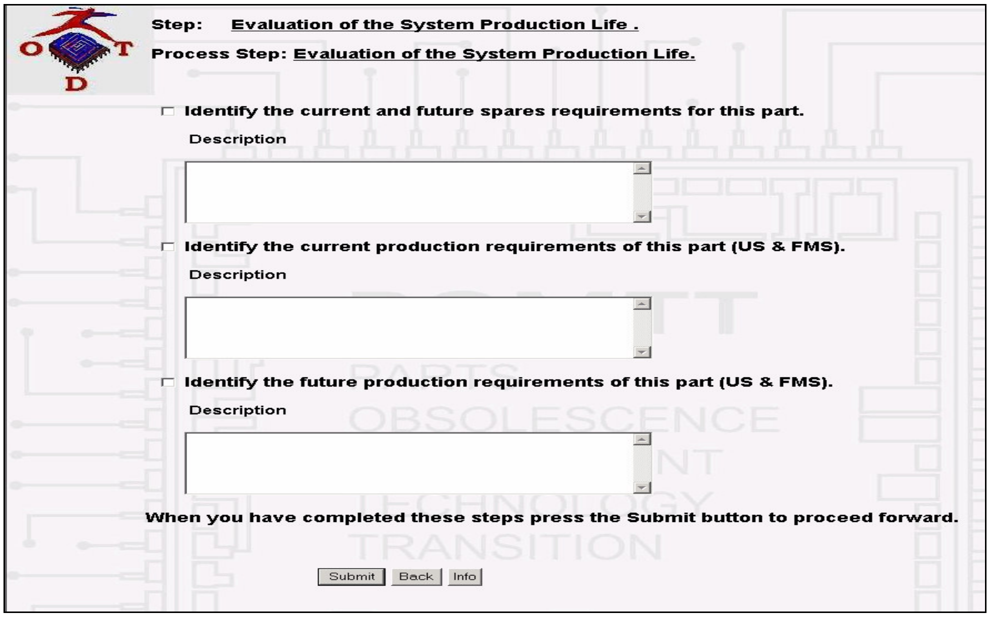


Figure 8.23 – Sample ODT Query

8.2.19 Help Pages

Each page throughout the ODT process has a link to help or info pages. These pages were developed to provide additional detail about each question or step in the process. (Figure 8.23)

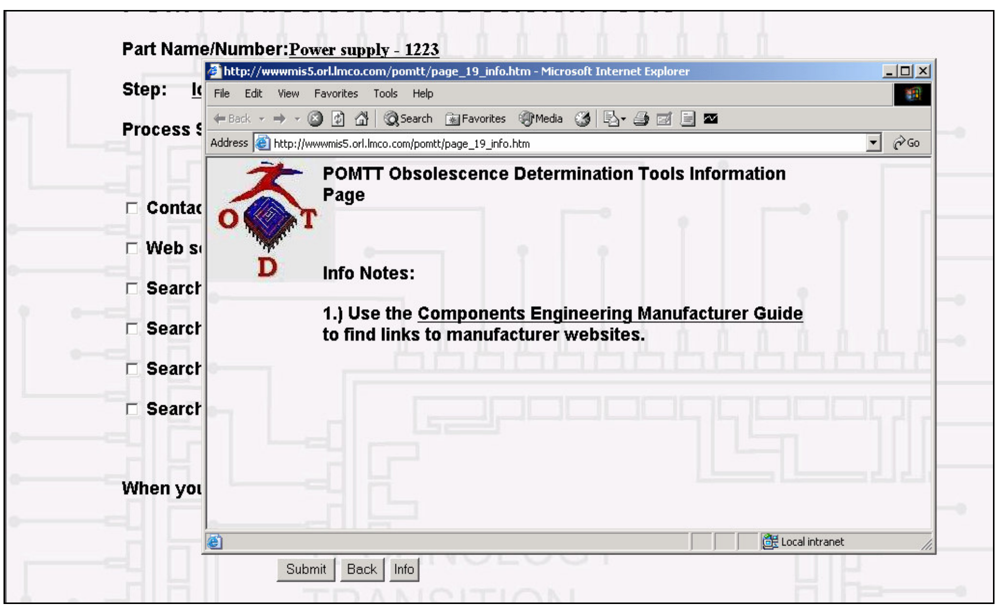


Figure 8.24 – Sample ODT Help Screen

8.2.20 ODT process

The ODT process is similar to several consumer software packages. The software asks a series of hierarchal controlled questions in order to populate data fields and it automatically follows the flow model to derive the best solution. (Figure 8.25)

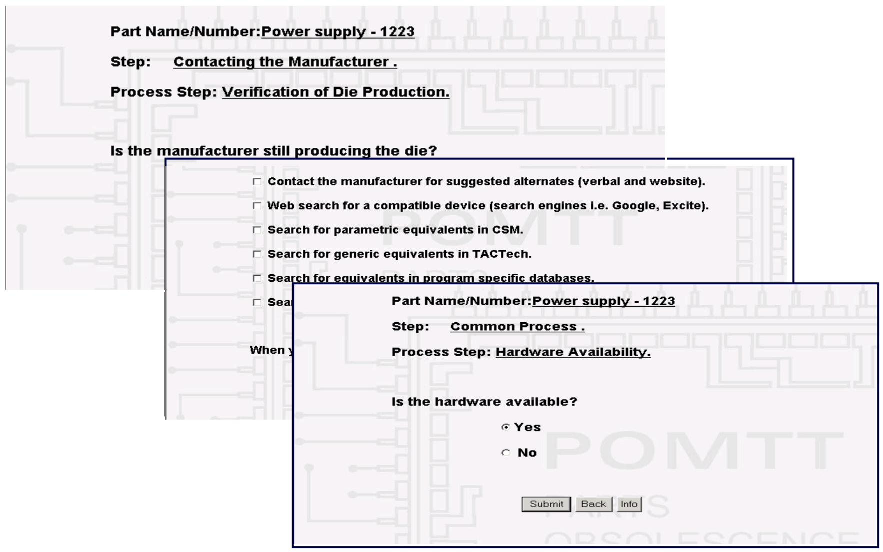


Figure 8.25 – User Input Examples

8.2.21 Links

The ODT also provides links to LM and external resources such as i2's TacTech, LMMFC-O Components Engineering Manufacturer's Guide, a listing of LMMFC Preferred Suppliers, and many others. These will help the user identify potential substitutes and manufacturers (Figure 8.26).

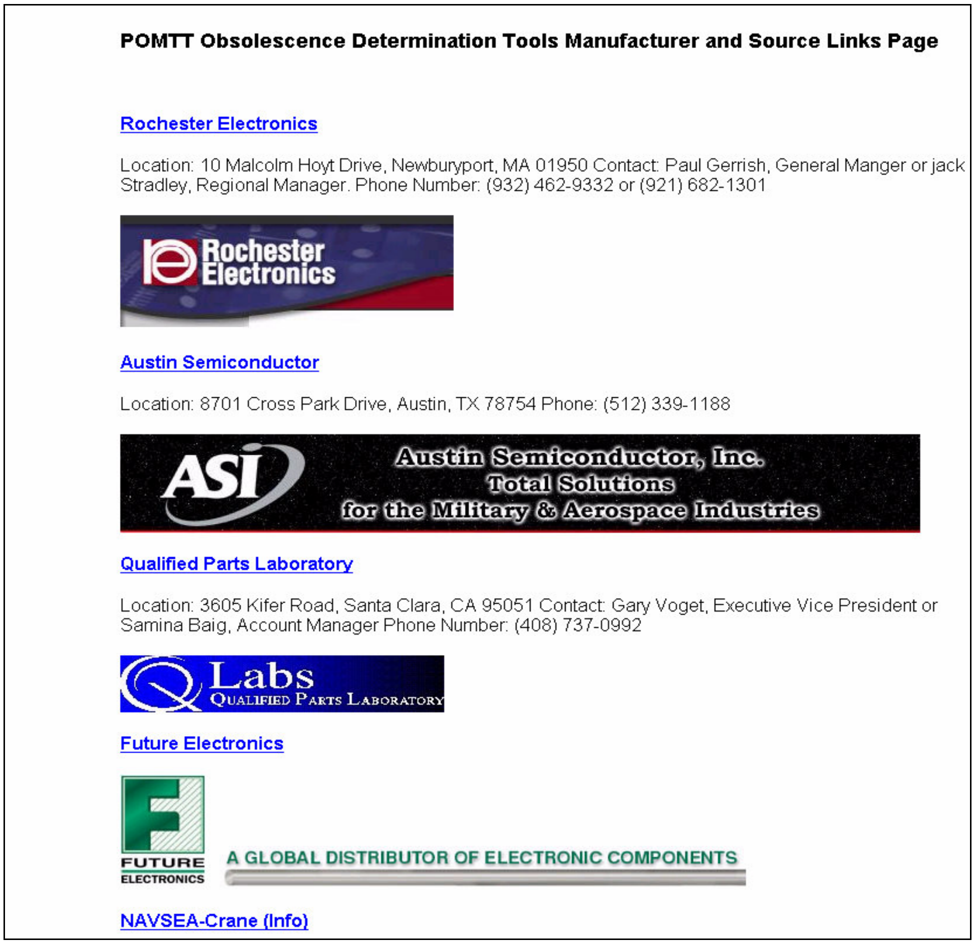


Figure 8.26 – ODT Links

8.2.22 The Combination of ODT and RADSS

With the completion of the ODT software LMMFC-O has two separate software tools integrated into an overall solution. First, the ODT solves day-to-day obsolescence issues, and RADSS 2000 takes on the more complex multi-alternative decisions such as redesigns. Taken together, the combination gives LM a complete obsolescence decision system (Figure 8.27).

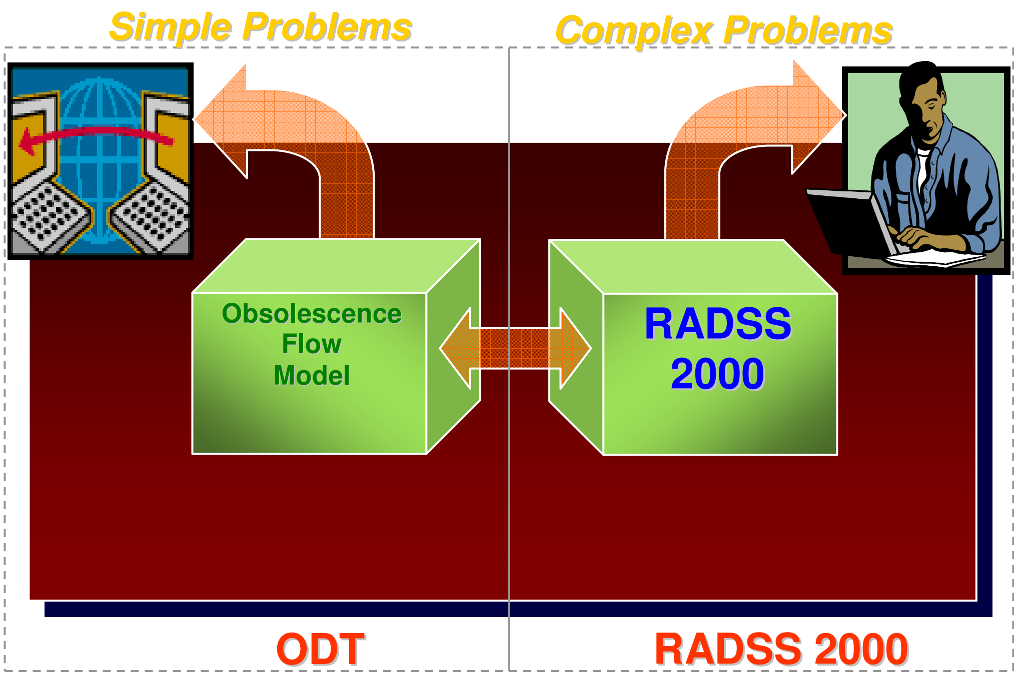


Figure 8.27 – ODT Structure

8.2.23 <u>RADSS POMTT Evaluation Cost</u>

The Tables below (8.10 and 8.11) illustrate the costs involved with developing and testing the RADSS model on the POMTT program. NOTE: The hourly rate was taken as a general average. Also, the two technical SMEs were used as a data source for the model, their time was considered at 4 hour per week for each.

Table 8.10 – ODT Cost Analysis Summary

Model Development				
Personnel	Hours Per Week	# Weeks	Hourly Rate	Total
2 Program Technical SME's	8	10	$100.00	$8,000.00
1 POMTT (model data input)	20	2	$100.00	$4,000.00
1 Management	2	52	$100.00	$10,400.00
1 Tool SME (Training)	2	2	$100.00	$400.00
1 Trainer (NGIT)	22	2	$105.00	$4,620.00
			Total Cost	$27,420.00

Once a model is developed for a certain decision that model will probably not need to be developed again (non-recurring cost), whether it is applicable to other obsolescence problems or not. However, there will be certain maintenance and management tasks that will need to take place (recurring cost).

8.2.24 New RADSS Development Cost

Below (Table 8.11) is an estimation of the cost for Lockheed Martin or any other company to use RADSS to tackle a new decision problem.

Table 8.11 – RADSS Model Cost Analysis Summary

Estimation of new Model Development				
LMC Personnel	Hours Per Week	# Weeks	Hourly Rate	Total
2 Program Technical SME's	8	10	$100.00	$8,000.00
1 POMTT (model Data input)	20	2	$100.00	$4,000.00
1 Management	2	10	$100.00	$2,000.00
1 Tool SME (Training time)	22	2	$100.00	$4,400.00
1 Tool SME (Maintenance)	1	10	$100.00	$1,000.00
Tools				
1 RADSS Trainer				$5,820.00
1 RADSS License				$25,000.00
			Total Cost	$50,220.00

This estimation considers the purchase of the RADSS software and training a SME to use the tool. The cost to train LCMMFC-O personnel is $10,220 (including the trainee's and trainer's time and cost).

This cost model includes the purchase of the RADSS license $25,000. Without the need for a license or training an expert the total cost would only be $15,000 to develop a new decision model. If a model already exists that could be used in another decision, the resources required would only consist of manpower for data input and management at a cost of $6,000.

8.2.25 Cost Savings RADSS with the ODT

In order to provide an estimate of the savings generated by the use of the RADSS/ODT, the matrix in Figure 8.28 was created to show the difference in decision times between two users faced with an obsolescence decision. The first user (Obsolescence SME) is a specialist experienced in obsolescence management and solution identification, and the second is a typical engineer (little experience) often tasked with solving obsolete part problems. The decision times were estimated based on typically observed times over the last 10 years of the LANTIRN program and are discriminated by the potential solutions (Simple part replacement, CCA level of impact, complete redesign of the part, or complete redesign of the board). Each of these is quantified in the number of man-hours required to *investigate* the problem and *propose* a solution. The number of hours required to *resolve* the problem however, is not included in the estimate although there is potential that this could decrease as the tool is developed and users get trained. It will however, provide as much detail on each solution as possible).

TASK	Obsolescence SME (10%)	Standard Engineer (90%)	RADSS W/ Complex Flow 1st Iteration	RADSS W/ Complex Flow 2nd Iteration*
Part Obsolescence Verification and Replacement Identification	**26 hours**	**39 hours**	**32 hours**	**30 hours**
System/Program Evaluation-Conception (CCA/LRU)	**20 hours**	**30 hours**	**25 hours**	**23 hours**
High Cost Part Alternatives (GEM, VHDL, etc) Evaluation-Conception	**40 hours**	**60 hours**	**50 hours**	**47 hours**
Complex Redesign (complete board/subsystem)	**80 hours**	**120 hours**	**100 hours**	**93 hours**
Total Potential Savings (per task)			**42 hours** **$4200**	**54 hours** **$5400**

Figure 8.28 –Savings Estimates

It is clear that a more experienced user will usually identify the fastest and least costly solution in a shorter period of time. The difference in solution times increases as the complexity of the problem increases (from 13 to 40 hours). However, since the use of the RADSS tool effectively trains the typical engineer every time it is used, the amount of hours needed to achieve a solution should decrease after each use of the tool.

It must be pointed out that the desire of program's management to be receptive to the analysis and the speed of the analysis must be taken into account. Current practice indicates that most (80-90%) obsolescence decisions are simple replacement solutions and can be solved in a relatively short amount of time (by both experienced and inexperienced engineers), with relatively small amount of data and variables.

More complex decisions (such as redesigns or component modeling and synthesis) will take longer, but are typically based on a relatively small amount of data, and usually must be decided in a short amount of time. The RADSS template was created to help reduce the model development time by providing a specified logic flow to help lead the decision maker by basing it on previous experience. Since the model was developed using an existing knowledge base it provides the most optimum path.

8.2.26 Conclusion

The RADSS 2000 tool addresses complex, multi-alternative decisions, but with a significant up-front learning curve for model development and data population. With the redesign template already established however, this schedule time will be reduced for and succeeding complex decisions. LMMFC-O found that, although RADSS is very powerful, there were still simple obsolescence decisions that LMMFC-O needed support on and RADSS would not be viable for these. Lockheed Martin spent six months creating a decision template for use in RADSS to solve an obsolete part problem on the LANTIRN/IRST program. RADSS 2000 worked very well and arrived at a decision that the SMEs recognized as correct. However, most obsolescence decisions must be made in only a few days and the process was too long. It was recognized that this long, detailed process is necessary when evaluating a critical, high cost decision, but it did not accurately reflect what LMMFC-O needed.

At LMMFC-O a significant number of people struggled with obsolete part problems every day. Usually these people were untrained in this decision process and needed a tool to help them solve these problems. The steep learning curve of the RADSS tool and the lengthy set-up time of the decision template were two areas that limited its use on LMMFC-O needs. Therefore, LMMFC-O undertook development of the Obsolescence Decision Tool (ODT).

The Obsolescence Decision Tool (ODT) addresses simple day-to-day obsolescence decisions by using an established, proven obsolescence methodology. It provides a common process for all engineers to access and trains users as they follow the flow. Because of its established methodology and training aspect, engineers will end up spending less time on the decision process. ODT is web based and user-friendly making for a common, corporate wide decision process. Because of the use of Microsoft .Net software, ODT can also be used as a stand-alone tool or as a GUI front end. The flow is customizable and easily tailored to individual locations.

The combination of ODT and the RADSS tool provides an obsolescence decision support process that is unique in the industry.

8.3 BAE/ Georgia Tech PEMS Reliability for Common Modules Pilot

BAE SYSTEMS Controls (BAE) developed a process for using Commercial Off-The-Shelf (COTS) components in their Full Authority Digital Engine Controls (FADEC) and common modules. Some of these COTS parts were commercially available Plastic Encapsulated Microcircuits (PEM) and they were very interested in their long-term performance. BAE SYSTEMS Controls therefore undertook a pilot evaluation with Georgia Tech to validate and exchange data using Georgia Tech's (GT) Physics of Failure (PoF) based Reliability Analysis. These processes analyzes a commercial IC's package and solder material properties and uses finite element analysis to predict future material failures.

8.3.1 <u>Background</u>

The BAE FADECs are mounted directly on commercial and military aircraft jet engines and experience many temperature cycle variations and have to endure high vibration in flight. By 2000, FADEC systems using PEMs had accumulated millions of device hours in systems.

BAE SYSTEMS Controls is also the repair and maintenance center for these systems. As part of the POMTT pilot project, Controls monitored the PEMs removed from the repaired engine controls. The parts that were replaced were tested at the part level and those that failed underwent further failure analysis.

From September 2000 through August 2002, 80 PEMs were removed, tested, and analyzed (see Figure 8.29).

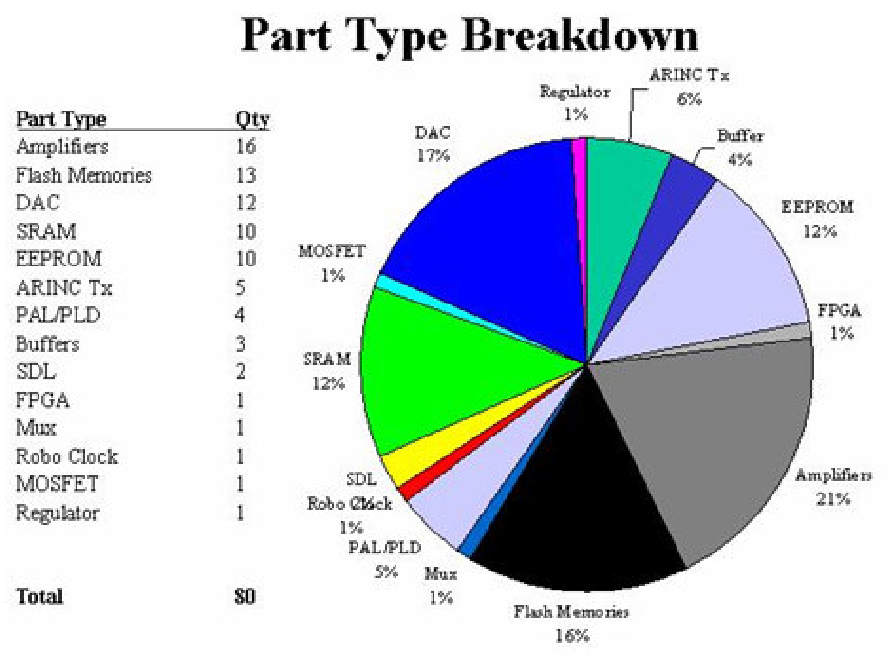


Figure 8.29 – Potential Failure Breakdown by Type

Of 80 total devices removed as potentially failed, approximately 36 (46%) were confirmed as failed. Twenty-three of these (28%) were proven to be functional and 21 (26%) were unable to be verified. Of the 36 verified failures, Failure Root Cause was determined on 26 of the devices (see Figure 8.30). All of the failures were induced or the result of application or circuit design issues. Considering only these results, it could be concluded that PEMs are as reliable as the previous generation of ceramic/hermetically sealed microcircuits.

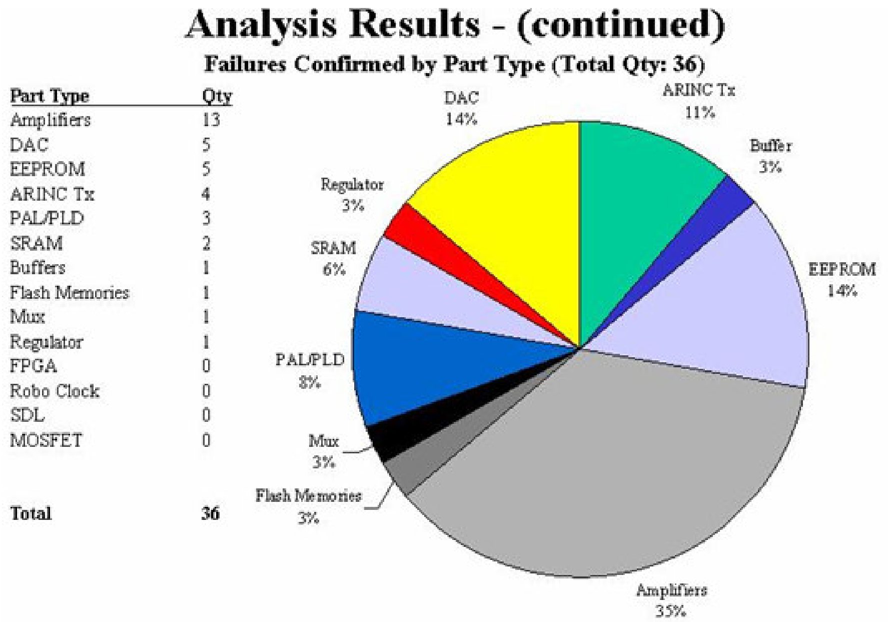


Figure 8.30 – Failure Results by Part Type

Of greater interest however, were the removed parts that were removed due to potential failure but actually tested okay at the part level. This can be partially explained by the limited capability of board-level test equipment to isolate failures to a single device. Often, this equipment isolates to 2 or 3 devices, called an “Ambiguity Group”. For economic reasons, all of the parts in the ambiguity group will be removed and replaced. Usually though, only 1 of the devices has actually failed.

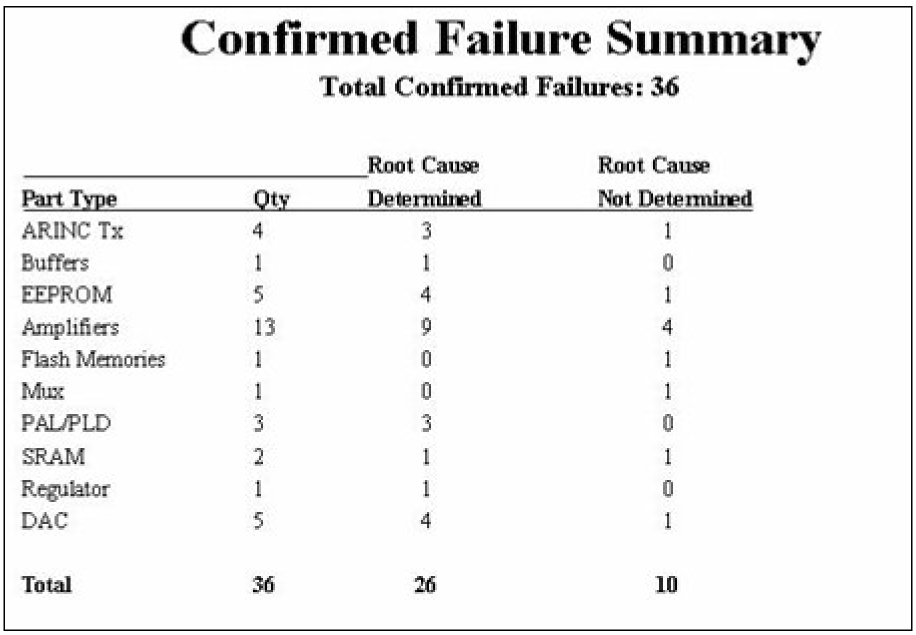
In some cases, all devices that were removed were tested and were found to be functional at the part level. One explanation for this type of unverified failure is a solder joint failure. Theoretically, if the solder were “touched up” on these devices, the board would once again function. Closer study of subsequent failures also drew attention to solder life as being a primary cause of electrical failure, and possibly more so in PEMs than in previous ceramic part designs.

Therefore, in August 2002, BAE SYSTEMS Controls presented these findings to the Mechanical Engineering staff at Georgia Tech. The purpose of the meeting was to determine if there was enough a statement of work to transfer BAE’s PEM failure data to Georgia Tech, receive GT’s PoF data and model updates, and work out additional details of a pilot project. The results were that Georgia Tech and BAE agreed to work together on a Physics of Failure study using finite element analysis of Ball Grid Arrays (BGAs).

8.3.2 Pilot Objectives and Approach

The overall goal of the pilot was to seek out failure mechanisms that were related to manufacturing of the devices and use Physics of Failure Reliability Analysis to validate the GT FEA BGA models so they can be applied to existing and future designs and applications. Failures caused by application, induced failures such as Electrical Overstress (EOS/ESD), and lot related defects were not included. The resulting data could be used to model and predict life under a variety of conditions.

By this time BAE's PEMs had accumulated over twenty million (20,000,000) operating hours on over 4,000 FADECs. Although PEMs were being used on the FADECS, it was not possible to calculate a total PEM/hour usage estimate since the number of PEMs used per FADEC varied depending on the age of the controller. The parts were in use from September 2000 on, and failure data was being captured by board assembly. As of the start of the pilot, this had resulted in the removal of eighty parts being removed and analyzed. Additional details of the type of parts analyzed and the analysis results are shown in Figures 8.31 and 8.32.



Confirmed Failure Summary

Total Confirmed Failures: 36

Part Type	Qty	Root Cause Determined	Root Cause Not Determined
ARINC Tx	4	3	1
Buffers	1	1	0
EEPROM	5	4	1
Amplifiers	13	9	4
Flash Memories	1	0	1
Mux	1	0	1
PAL/PLD	3	3	0
SRAM	2	1	1
Regulator	1	1	0
DAC	5	4	1
Total	**36**	**26**	**10**

Figure 8.31 – Failure Confirmation Summary

Root Cause Category Summary

Root Cause Determined Qty: 26

Root Cause Category	Total
EOS	15
Lifted Ball Bonds	6
Partial Page Write	3
ESD or Gate Oxide Defect	1
Package Defect	1
Total	**26**

Figure 8.32 – Root Cause Summary

Initially, Georgia Tech's analysis data and previous experience agreed with the BAE findings. With the improvements in wafer processing and with improved packing materials and processes, modern PEMs had shown to have very few problems related to moisture penetration, parametric drift, or mechanical integrity. With no internal die cavity, these devices were also superior to the ceramic parts in regard to electromigration and corrosion.

All of these verified part failures are summarized in Table 8.12 as follows:

Table 8.12 – Failure Root Cause Matrix

Root Cause Category							
Part Details			Failure Type				
Part Number	Package Type	QTY	Electrical Overstress	Lifted Ball Bonds	Partial Page Write	ESD or Gate Oxide Defect	Package Defect
Part #1	PLCC28	1		X			
		1	X				
		1				X	
Part #2	SOIC8	1		X			
Part #3	PLCC28	4		X			
Part #4	SOIC20	1	X				
Part #5	SOIC16	6	X				
Part #6	SOIC16	2	X				
Part #7	PLCC28	3	X				
Part # 8	SOJ32	1	X				
Part #9	PTO220-3	1	X				
Part #10	PLCC32	3			X		
		1					X

The use of high-density, low-lead compliance interconnects, such as Ball Grid Arrays presented a challenge. The Coefficient of Thermal Expansion (CTE) mismatch between various devices and board materials, when subjected to the temperature extremes of airborne equipment, was considered the biggest technical problem to overcome.

Since Georgia Tech had developed solder life modeling software, BAE held a meeting with Dr. Suresh Sitaraman at GT to discuss their progress and determine if this research could be applied to BAE's applications and parts. Because of this meeting, BAE SYSTEMS Controls entered into a partnership to demonstrate the ability of, improve, and validate the GT BGA models and help predict solder life of BAE's BGA packaging.

The correlation and validation of the BGA solder life models would be done by fabricating test boards using BGA configurations applicable to BAE SYSTEMS Controls' products, conduct solder life analysis on these configurations, testing the configurations in thermal cycling, comparing results of analysis and testing, and developing and refining reliability distributions based on results of testing and analysis

8.3.3 Pilot Project Tasks

BAE SYSTEMS Controls would do this by providing data on the BGA configurations (see Table 8.13) included on the proposed test boards (see Figure 8.33). This includes:

- Vendor datasheets giving detailed package dimensions
- Warpage and expansion measurements of each package
- Dimensions of semiconductor die as measured by X-ray or cross-section
- Detailed material properties and internal geometries of the packages analyzed by Georgia Tech.
- Fabricate test modules incorporating BGA components.

Table 8.13 – BGA Component Configurations

Description	Pitch (in)	Array Type	Matrix Dimension (in)	Ball Dia. (in)
IBM. 304 CCGA Daisy Chain (1)	0.050	Full	0.750 x 0.900	0.022 (2)
IBM 625 CCGA Daisy Chain	0.050	Full	1.200 x 1.200	0.022 (2)
Amkor 432 sBGA Daisy Chain	0.050	Partial	1.500 x 1.500	0.030 (3)
Amkor 388 PBGA Daisy Chain	0.050	Partial	1.250 x 1.250	0.030 (3)
White Tech. 219 PBGA Synchronous DRAM	0.050	Partial	0.750 x 0.750	0.033 (3)
Lattice 388 PBGA (1)	0.050	Partial	1.250 x 1.250	0.030 (3)
Motorola 360 CBGA PowerPC	0.050	Full	0.900 x 0.900	0.035 (3)
GSI 209 PBGA Sync Burst SRAMs	0.039	Full	0.702 x 0.390	0.024 (3)
Galileo 388 PBGA System Controller	0.050	Partial	1.250 x 1.250	0.030 (3)
AMD 64 PBGA Boot Block Flash Memory (1)	0.039	Full	0.276 x 0.276	0.024 (3)
Intel 64 PBGA Boot Block Flash Memory	0.039	Full	0.276 x 0.276	0.017 (3)

Notes:

1. Detailed part construction and material properties were obtained for these parts for Georgia Tech finite element model development.
2. The CCGA column diameter is 0.022 inch and its length is 0.087 inch.
3. The ball diameter reported is prior to component soldering.

BAE would conduct thermal cycle testing (-55ºC to 95ºC) on the modules and would correlate testing and analysis results and develop reliability distributions for use by the Georgia Tech. BAE would also prepare a final report at the pilot completion.

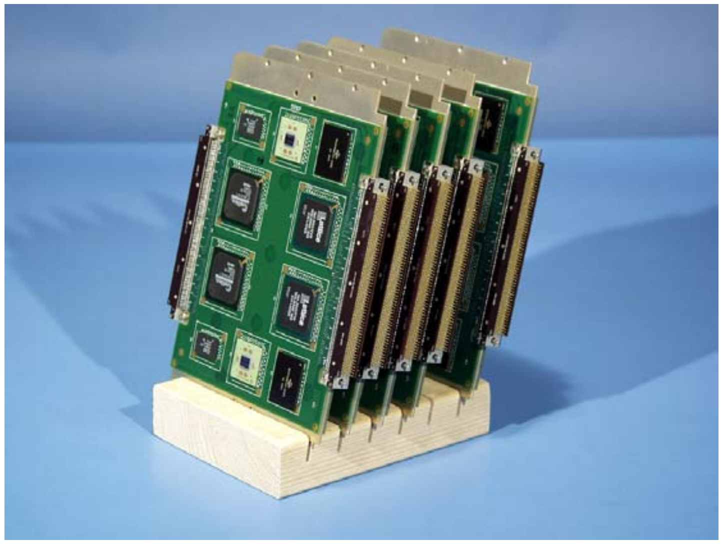


Figure 8.33 – Test Modules

The Georgia Institute of Technology was responsible for conducting solder life analysis on the component configurations and would correlate testing and analysis results for the resulting reliability distributions.

8.3.4 <u>Schedule</u>

The project was approved in late 2002 and began in December of the same year. The major tasks included the data analysis and model development by Georgia Tech and the long-term board testing performed by BAE (see Figure 8.34).

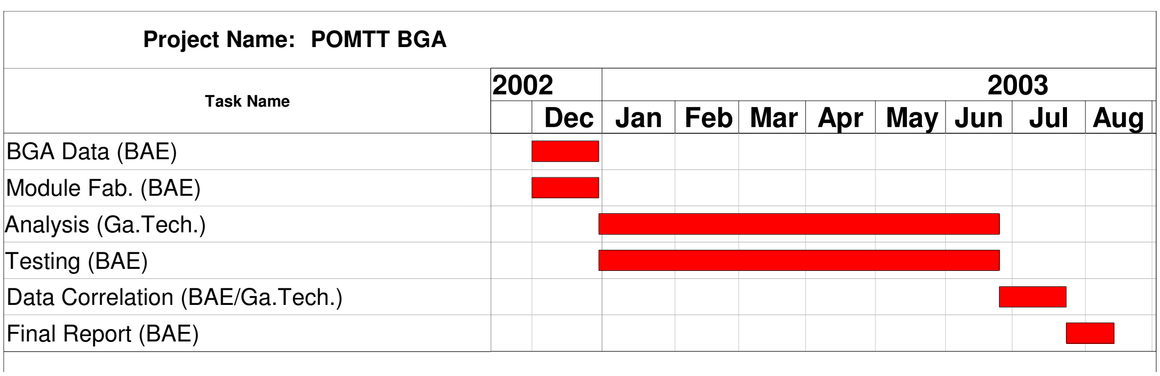


Figure 8.34 – Schedule

8.3.5 <u>Pilot Details</u>

In electronics design and packaging, package connection area arrays are one technology being utilized to meet the current demands of the industry. These arrays come in several variations where the most common configurations are Plastic Ball Grid

Array (PBGA), Flip Chip BGA (FCBGA), Ceramic Ball Grid Array (CBGA) and Ceramic Column Grid Array (CCGA). Area arrays are popular due in large part to their small footprint compared to the number of I/O available. This is achieved by utilizing an array of solder connects that are underneath the package rather than protruding from the edge as seen in other recent technologies. They have a much greater I/O capability than comparably sized Quad-Flat-Packs (QFPs), but actually have larger lead pitches, which in turn improves manufacturability. Area arrays also have better heat dissipation by design.

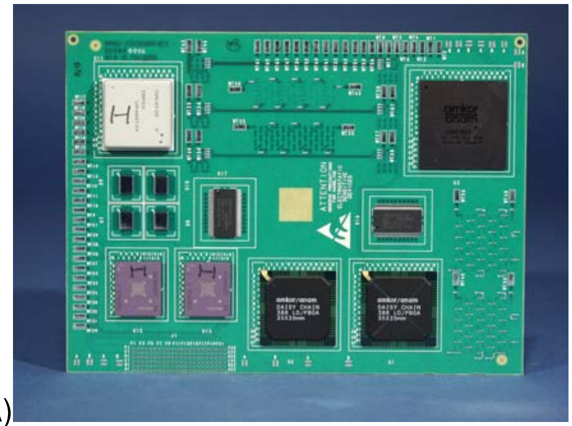
Due to their inherent advantages, part manufacturers are packaging many popular chips as area array parts. To satisfy electrical functional requirements it is becoming increasingly necessary to use these advanced packaging schemes. However, in high reliability equipment it is important to have a thorough understanding of package durability. How the part and board Coefficient of Thermal Expansion (CTE), solder materials and shapes, and environment (temperature, vibrations, atmosphere, etc.) combine and affect the part are some of the most important considerations to be understood. These must be known before proper application of the parts can be made.

The durability of the individual BGAs are established by subjecting them to a battery of piece part tests such as thermal cycling from –55 to +150 deg C, high pressure humidity testing, high temperature burn-in electrical stress testing, etc. Unfortunately, these tests do not shed any light on the reliability of the next level of interconnect, namely the solder joints between the BGA and the printed wiring board (PWB) that it is attached to. This information can only be gained through the use of module level testing coupled with analytical modeling.

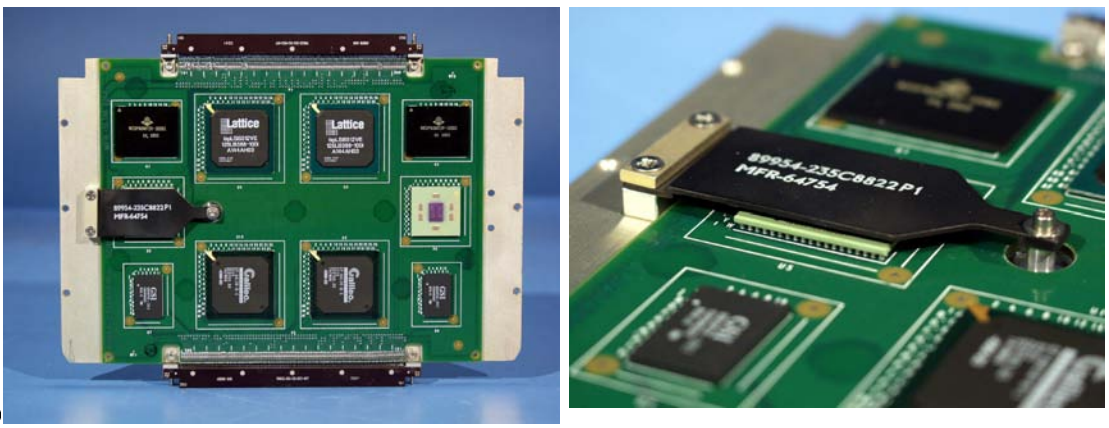
Therefore, three BGA types were selected for detailed finite element analysis by BAE and the Georgia Tech team. This evaluation included part cross sectioning (to obtain detailed part makeup and dimensions), as well as thermo mechanical measurements (such as CTE and warpage). Much of this information was used as input to create and refine detailed finite element models. To complement the analytical models, durability test modules were designed, fabricated and subjected to thermal cycling testing.

8.3.5.1 <u>Durability Test Module Construction</u>

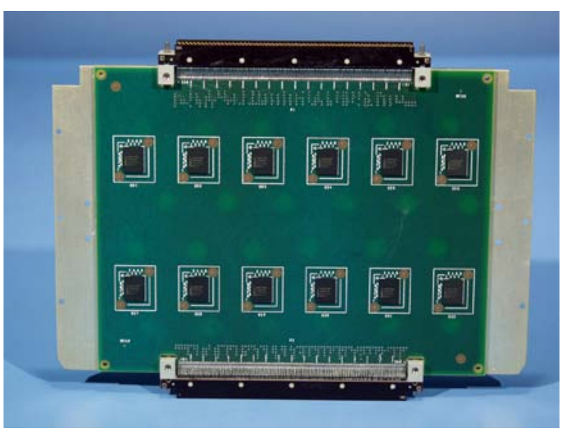
The term “Module” is used to describe a typical circuit card assembly (CCA), where there is a central aluminum heat sink core with two multilayer boards, one bonded to each side of the aluminum heat sink. Parts are populated on the outer surface of the printed wiring board (PWB) with tin-lead eutectic solder. The modules used to perform the BGA thermal cycling durability testing are shown in Figure 8.35A, B, and C. The test PWB thickness and copper content is typical of a 12 layer PWB used in many designs.



(A)



(B)



(C)

Figure 8.35 – Test modules.

(A) Two boards bonded to a central heatsink.

(B) 2003 test module with auxilliary heatsink.

(C) Side 2 of the 2003 test module.

The test vehicle also includes an auxiliary heat sink (Figure 8.35B), which would typically be used to maintain the device junction temperature to a predetermined level. An exploded view of the assembly prior to heat sink bonding is shown in Figure 8.36 and a dimensioned sketch of the cross-section is given in Figure 8.37.

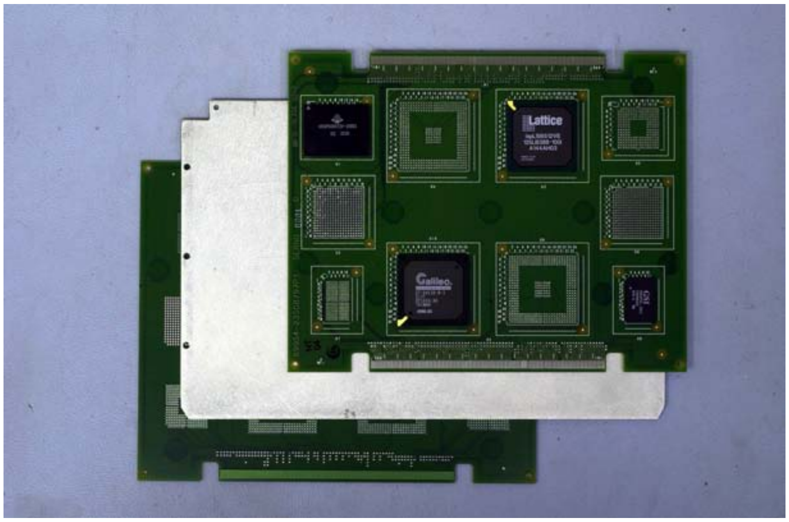
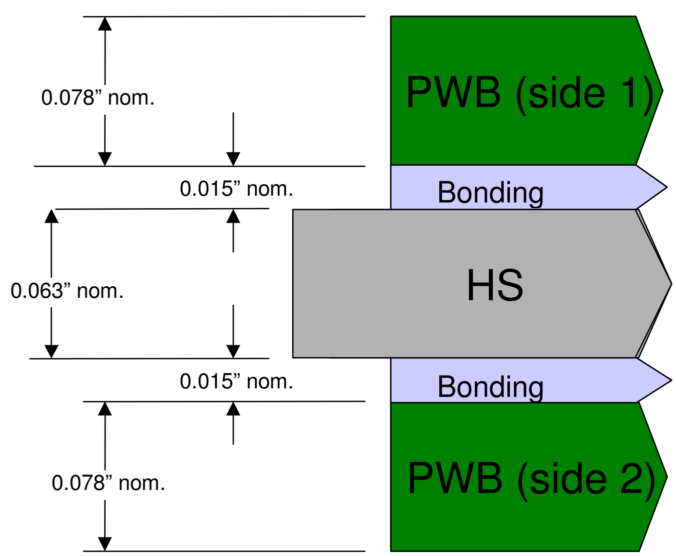


Figure 8.36 - Module Exploded View.

Note: The bonding sheets located between the PWBs and the heat sink are not shown.



Area 1 -- **Figure 8.37 - Dimensioned**

As seen in Figure 8.38, the auxiliary heat sink attachment the top of the BGA results in additional loads being applied to the top of the BGA. The loads are applied to the PWB through the solder causing an increase in solder ball stress. In an effort to minimize these solder stresses, a compliant thermally conductive bond 0.005 to 0.030 inch thick is formed between the heat sink and the part. In the present test vehicle the left BGA (with the heat sink) is identical to the right BGA (without the heat sink) to allow determination of the relative life of a BGA with an auxiliary heat sink to one without.

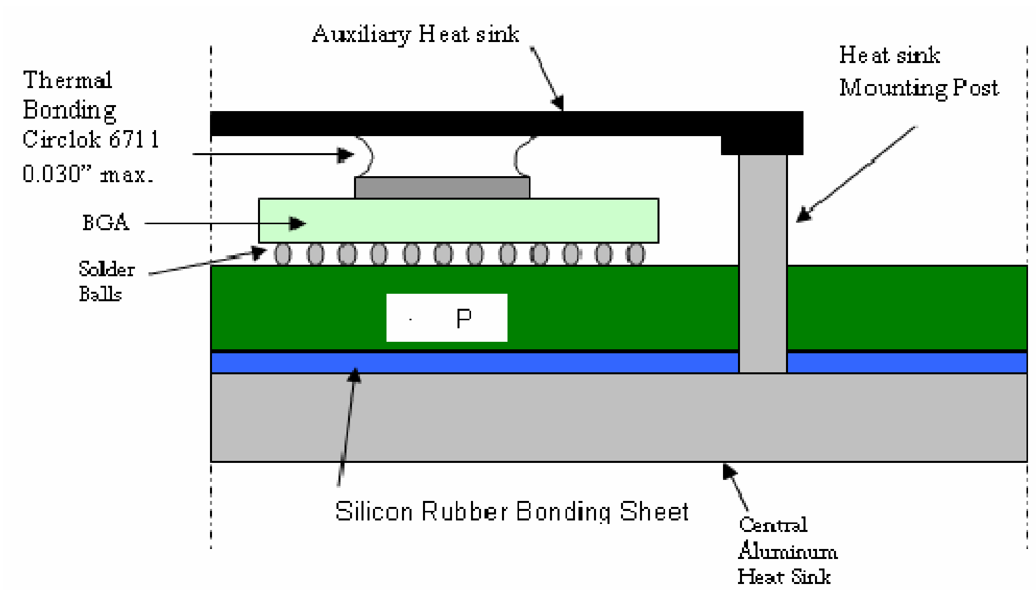


Figure 8.38 - Module Exploded View.

Two types of daisy chain board types were thermal cycled. The first board was comprised of thermount (TM DuPont Inc.) outer layers laid over a core of GFG glass epoxy (Note: Thermount is a material that is easily laser machined during the formation of microvias). The second board is comprised of GFG epoxy coated glass fabric. Each board contains four, ½ ounce plane layers distributed throughout the PWB stack-up. The thermount board is fabricated in accordance with a BAE assembly drawing while the GFG board is fabricated IAW another BAE drawing as well. Both boards utilize copper defined PWB pads (e.g. non-soldermask defined) with a select tin-lead eutectic hot oil reflow finish.

The 2003 durability test board has the same BGA pad configuration, PWB finish, layer count, and plane distribution as the daisy chain test modules. The 2003 modules are designed to evaluate the performance of functional BGAs rather than daisy chain BGAs. While the continuity monitoring scheme is more complex, the method employed on the 2003 module has the advantage of evaluating devices with the exact internal construction features manufactured on the exact fabrication line as the parts being considered for service. The 2003 module uses 12 layer GFG boards. A typical GFG

PWB mounted to an aluminum heat sink with silicon rubber bonding sheets has a coefficient of thermal expansion (CTE) that ranges between 18 and 22 ppm/C (parts per million per degree Celsius).

A summary of the components assembled to the various modules and boards is given in Tables 8.14 and 8.15.

Table 8.14 – Daisy Chain Module Part Population Summary

Board Configuration: 235C8268P6			
Modules: (1) has PWB SNs 2 and 10, (2) has PWB SNs 4 and 9, (3) has PWB SNs 7 and 8			
Applicable PWB SNs:	0002, 0004, 0007, 0008, 0009, 0010		
Part Population:	Part Number	Occurances:	Reference Designators:
IBM 625 CCGA "M"	B064738 U1800P97 "M"	1	U11
IBM 304 CCGA	IBM TV936 (PB089936)	2	U12, U13
IBM 625 CCGA Spiral	B064738 U1800P97 "S"	1	U11 (Sn 4 and 7 only)
IBM 304 CCGA Spiral	IBM TV936 (PB089936) "S"	2	U12, U13 (Sn 7 only)
Tessera 46 mBGA	TV46i	4	U7, U8, U9, U10
Amkor/Anam 388 PBGA	388 LD/PBGA	2	U1, U2
Amkor/Anam 432 SBGA	Amkor/Anam SBGA 432	1	U3

Board Configuration: 235C8750P1			
Module 1 PWB SNs:	0012, 0013		
Part Population:	Part Number	Occurrences:	Reference Designators:
IBM 625 **CBGA**	B064738 U1800P97 "B"	1	U11
IBM 304 CCGA	IBM TV936 (PB089936)	2	U12, U13
Tessera 46 mBGA	TV46i	4	U7, U8, U9, U10
Amkor/Anam 388 PBGA	388 LD/PBGA	2	U1, U2
Amkor/Anam 432 SBGA	Amkor/Anam SBGA 432	1	U3
Module 2 PWB SNs:	0016, 0021		
Part Population:	Part Number	Occurrences:	Reference Designators:
IBM 625 CCGA "M"	B064738 U1800P97 "M"	1	U11
IBM 304 CCGA	IBM TV936 (PB089936)	2	U12, U13
Tessera 46 mBGA	TV46i	4	U7, U8, U9, U10
Amkor/Anam 388 PBGA	388 LD/PBGA	2	U1, U2
Amkor/Anam 432 SBGA	Amkor/Anam SBGA 432	1	U3

Table 8.15 - 2003 Module Part Population Summary

2003 Module Configuration:
Applicable SNs: 5C, 6C, 6D, 7D, 8A

SN:	Side 1 PWB	Side 2 PWB	Comments
5C	235C8797P1	235C8799P2	AMD U25-27 not populated
6C	235C8797P1	235C8799P2	AMD U25-27 not populated
6D	235C8797P1	235C8799P1	Intel fully populated
7D	235C8797P1	235C8799P2	AMD U25-27 not populated
8A	235C8797P1	235C8799P1	Intel fully populated

Board Configuration: 235C8797P1
Applicable SNs: 5C, 6C, 6D, 7D, 8A

Part Population:	Part Number	Occurrences:	Reference Designators:
GSI 209 PBGA	GS816V73C-200IT	2	U7, U8
White 219 PBGA	WEDPN8M72V-100Bi	2	U1, U2
Lattice 388 PBGA	ISPLSI5512VE-125LB388	2	U3, U4
Galileo 388 PBGA	GT-64130-B-1-IO66-00	2	U9, U10
Motorola 360 CBGA (HiCTE)	MPC7410RX450LE	2	U5, U6

Board Configuration: 235C8799P2
Applicable SNs: 0006-C, 0007, 0008

Part Population:	Part Number	Occurrences:	Reference Designators:
AMD 64 PBGA	Am29LV640MU	12	U21, U22, U23, U24, U25, U26, U27, U28, U29, U30, U31, U32

Board Configuration: 235C8799P1
Applicable SNs: 0005, 0006-D

Part Population:	Part Number	Occurrences:	Reference Designators:
Intel 64 PBGA	28F640C3	12	U21, U22, U23, U24, U25, U26, U27, U28, U29, U30, U31, U32

8.3.5.2 Thermal Cycle Description

The thermal cycle profile chosen for the solder joint durability evaluation is illustrated in Figure 8.39. The thermal cycle is from –55 to +95 degrees C with half hour ramps and dwells. The lower bound includes the lower temperature requirement of many avionic systems. The upper bound represents the maximum upper temperature that the PWB usually needs to be to keep the device junction temperatures from exceeding 125 degrees C. The 30 minute dwell is chosen so that the entire assembly reaches thermal equilibrium at the temperature extremes and that the solder fully creeps at the hot extreme of the thermal cycle.

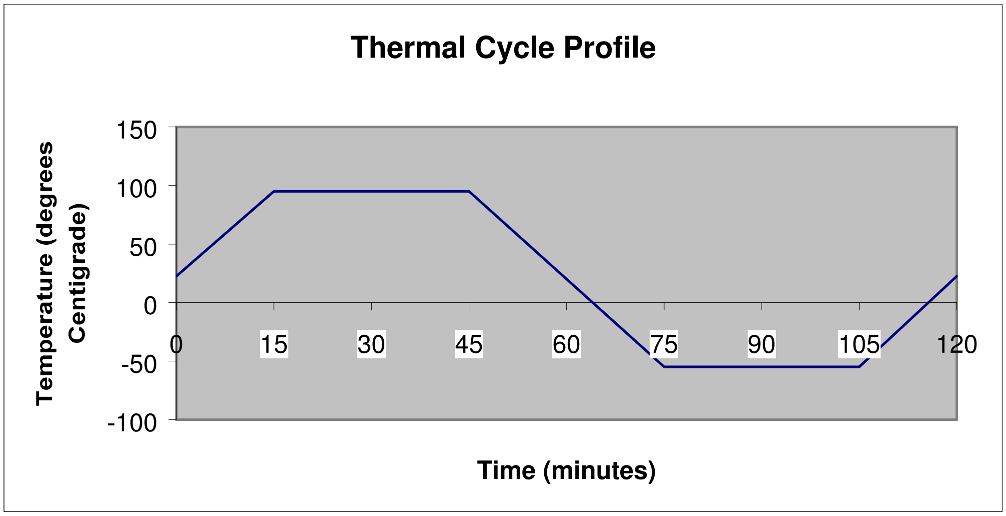


Figure 8.39 - Thermal Cycle Profile

8.3.5.3 BGA Electrical Monitoring

The two test modules designed for the thermal cycle testing utilize different monitoring approaches. Daisy chain continuity monitoring was utilized on the 235C8268 and 235C8750 modules, while diode current monitoring was used on the 2003 modules fabricated with 235C8797 and 235C9799 PWBs.

For the daisy chain continuity test module, an Agilent 34970A Data Acquisition Unit with either a HP 34901A 20-Channel Multiplexer or a HP 34908A 40-Channel Single-Ended Multiplexer was used to monitor continuity. There is also a thermocouple attached to “count” the number of thermal cycles. The daisy chain board design was configured such that at least 2 loops were used for each part. The first loop only went through the balls near the corner and the second loop strung together the majority of the remaining balls. Note that none of the daisy chained BGAs had die with the exception of the 46 pin Tessera uBGA. Typically, each device type (PBGA 388, CCGA 304 etc.) was connected to its own monitoring loop. Circuits are flagged as open if a resistance of greater than 200% of its initial resistance was recorded. The data acquisition unit scanned the monitoring channels every 5 minutes and, approximately once per week, the scan was stopped and the data was stored. If a failure was logged in an instance where multiple parts were on a common daisy chain loop, manual resistance probe testing was used to identify the failed component. Once located and verified, the bad loop was jumpered out with hard wires.

Parts that have failed were either reinserted into the chamber (after jumpering the daisy chain to restore continuity) or were selectively removed from the board for failure analysis. The boards were designed so that parts removed would not disrupt any routing to other devices. That way the remainder of the board will still function as a board under test. However, care still had to be employed during the removal process. Because, although excising a part would not disrupt other parts, removal machining operations must be performed very carefully to minimize vibration or mechanical shock that could affect the observable life of the remaining parts under test.

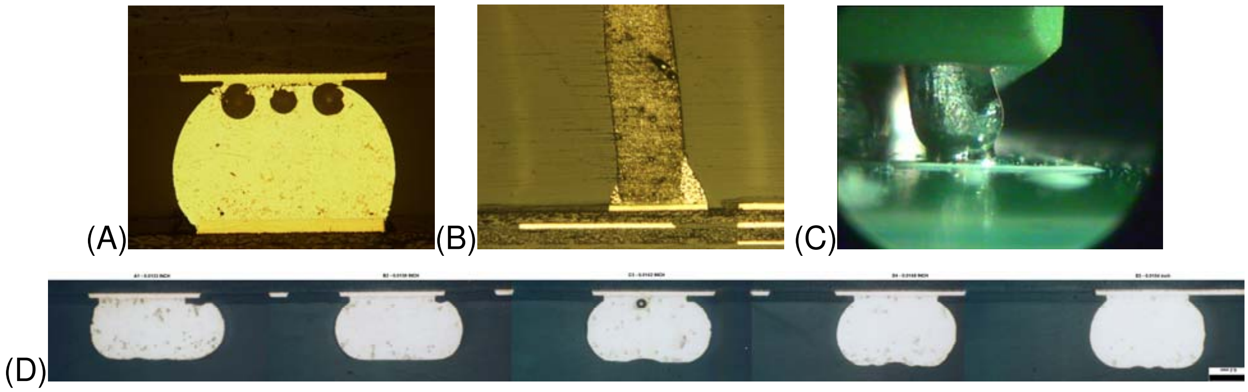
The 2003 test modules were designed to interface with a monitoring board. In the PWB design, individual traces were routed to groups of corner balls both the outer edge of the package and also at the die corners. The parts were characterized with a curve tracer to determine the characteristics of the balls and the device's power and ground pins. The monitoring board that the durability test board plugs into (233C8214P1) monitors the current through reverse protection diodes in the BGAs used to protect I/O pins from over voltage conditions. The monitoring board utilizes a PAL device to monitor the current which can be toggled to verify the health of the monitoring circuit. The monitor board interfaces with a PC parallel port to save the data to a file.

8.3.5.4 Area Array Geometric and Thermo mechanical Characterization

Any fatigue model requires an accurate description of the BGA solder joint shape after reflow. In the pilot study, the solder joint shape after reflow is obtained by cross-sectioning the re-flowed ball. In a cross-section of this type, the most significant results obtained are: the "package to PWB" solder stand-off height, and the uniformity of the solder ball (e.g., is the solder squashed excessively by the package weight and are the package and PWB solder pad diameters comparable?). The joint can also be examined for:

1. Metallurgical bonding
2. Solder wetting (e.g. is the solder wetting to the sides of the PWB pad)
3. Thickness and type of nickel plating that may be on the BGA solder pad
4. The type of solder alloy used in the original BGA ball
5. The presence and location of solder voids
6. The degree of package warp after soldering (e.g. is the solder stand-off height the same in the center as it is on the edges?)

Generally, a uniform ball that is not too squashed on BGA and PWB solder pads that are comparable in diameter is desirable. It is preferred that the solder pads on the BGA and the PWB be non-solder mask defined. However, as will be observed later, all of the plastic BGAs in this study had solder mask defined pads rather than non-solder mask defined pads. As is seen in Figure 8.40, a broad spectrum of solder shapes were observed in the present study.



(A) (B) (C) (D)

Figure 8.40 – Photographs of various area array solder configurations.

(A) 388 daisy chain PBGA. Note that the PWB pad matches the BGA package pad but not the BGA package soldermask opening and as a result, the solder stress is significantly increased at the ball to package interface. The stress is further concentrated in this region by the presence of large voids that have accumulated at the top of the joint.

(B) Column grid array solder joint to the PWB pad. This is a 0.022 inch diameter column soldered to a 0.030 inch PWB pad. Note that the column does not self center very well.

(C) Non-reflowing (90Pb/10Sn) ball soldered to the PWB pad with insufficient solder paste causing a necking of the solder joint above the PWB pad. The stress concentration formed by the neck will reduce the fatigue life substantially.

(D) Over-molded PBGA similar to the PBGA 388 subject to reflow on a glass plate. This is a diagonal section plane going through balls A1 (left) to E5 (right). The solder heights vary dramatically. From left to right they are 0.0133, 0.0136, 0.142, 0.0148 and 0.0154 inches.

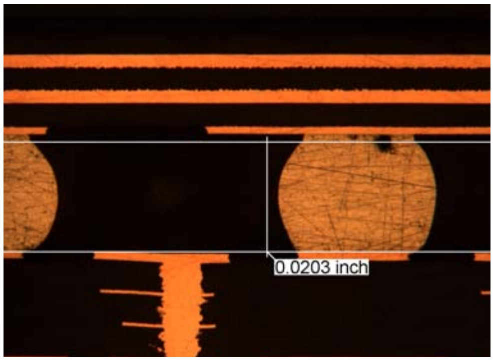
Once all the BGA pad design, solder paste volume, package warpage, board warpage and other process details have been ironed out, the minimum geometric input needed for a BGA life model is the solder stand-off height. In an assembled condition, package standoff height becomes an important factor. The solder attach becomes the compliant region between the PWB and the area array when the assembly is subjected to thermo mechanical mechanisms. In general, greater standoff height leads to greater compliance and longer life. All of the BGAs in the 2003 test module were cross-sectioned after soldering to the PWB to determine the solder shape and the stand-off height. A summary of the standoff heights compared with the original ball diameter is given in Table 8.16.

Table 8.16 – Solder Ball Heights Before and After Reflow.

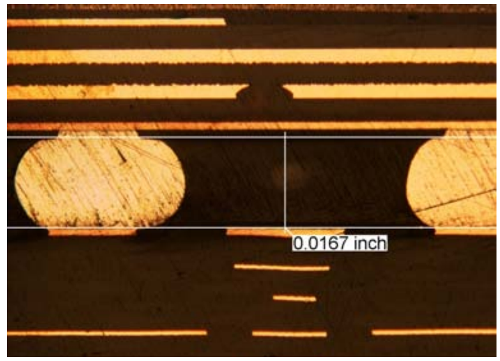
Description	Ball Dia. Before Soldering (in)	Ball Height Before Soldering (in)	PWB Pad Dia. (in)	Min Ball Height As Soldered (in)	Max Ball Height As Soldered (in)	Average Ball Height As Soldered (in) (1)
IBM 304 CCGA (2)	0.022	0.087	NA	NA	NA	NA
IBM 625 CCGA (2)	0.022	0.087	NA	NA	NA	NA
Amkor 432 sBGA	0.030	0.024	NA	NA	NA	NA
Amkor 388 PBGA	0.030	0.024	NA	NA	NA	NA
White Tech. 219 PBGA	0.033	0.024	0.024	0.0186	0.0188	0.0187
Lattice 388 PBGA	0.030	0.026	0.023	0.0167	0.0203	0.0185
Motorola 360 CBGA	0.035	0.035	0.034	NA	NA	NA
GSI 209 PBGA	0.024	0.020	0.016	0.0165	0.0182	0.01735
Galileo 388 PBGA	0.030	0.024	0.023	0.0191	0.0212	0.02015
AMD 64 PBGA	0.024	0.016	0.016	0.0153	0.0153	0.0153
Intel 64 PBGA	0.017	0.010	0.012	0.0155	0.0158	0.01565

(1) Average ball height has been calculated because part warpage leads to varation in standoff across the package.
(2) Spiral Columns have a height of 0.100"

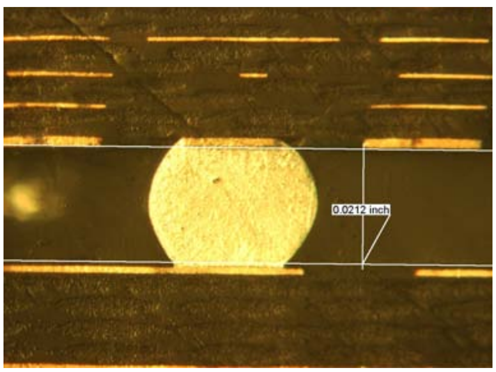
Some example cross-sections are shown in Figures 8.41 and 8.42. It should be noted that the PBGA 388 manufactured by Lattice and Galileo had the largest variation in solder stand-off height due to part warpage. A variation in height leads to a situation where, a certain solder joints have more or less compliance than other joints on the particular BGA.



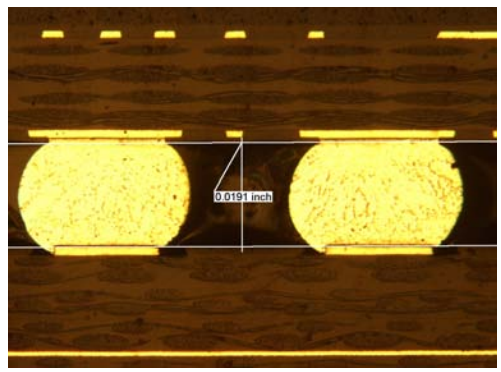
Lattice 388: 0.0203" @ corner



Lattice 388: 0.0167" @ center

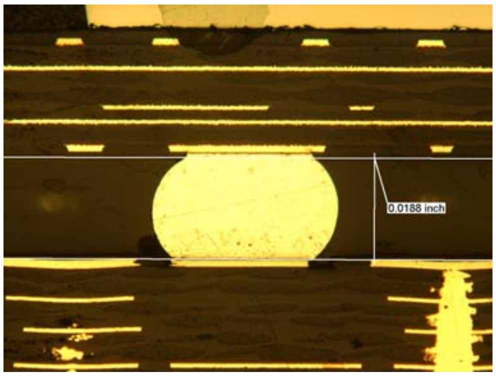


Galileo 388: 0.0212" @ corner

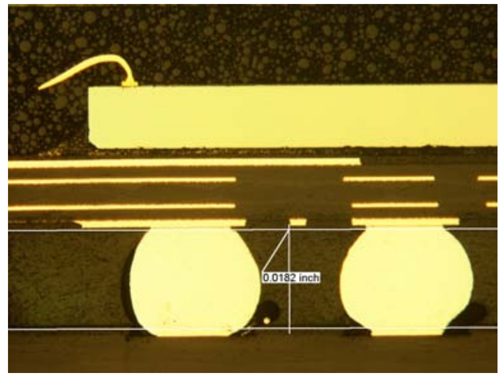


Galileo 388: 0.0191" @ center

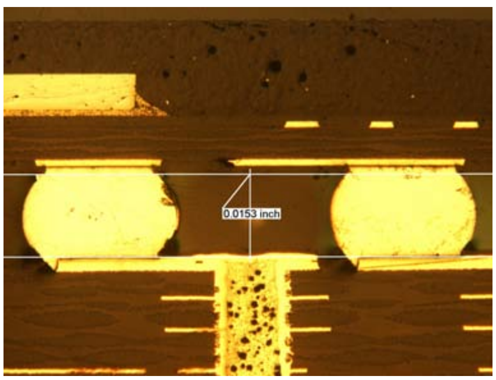
Figure 8.41 – Over-molded PBGA 388 solder standoff height measurements.



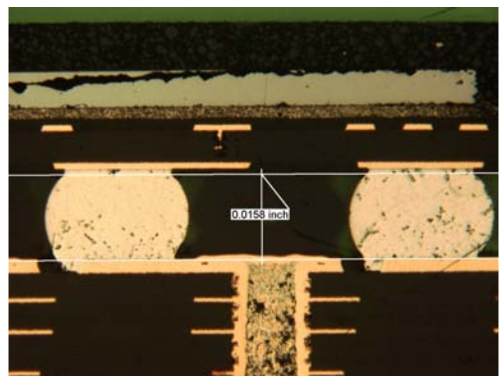
White 219: 0.0188" @ corner



GSI 209: 0.0182" @ corner



AMD 64: 0.0153" @ corner



Intel 64: 0.0158" @ corner

Figure 8.42 – Solder standoff height measurements for the molded and diced PBGAs. (Much less warped than the over-molded PBGAs.)

Given the wide range of construction differences between PBGAs, it is usually necessary to characterize a PBGA very early in the part selection process to determine if it will be suitable for a particular application. Moiré' Interferometry measurement techniques are useful means of determining package warpage and CTE. In addition, as illustrated in the following Georgia Tech analysis section (Section 8.3.6), Moiré' measurements of a cross-sectioned PBGA assembly that is soldered to a PWB that is mounted to the heat sink can be used to correlate the analytical finite element model results to the actual hardware being studied.

Area 11 -- In the region under the die in the center of the part, there are fewer fringes that the outboard regions indicating die is reducing the CTE in the center of the part.

To obtain the CTE of a BGA using the Moiré' Interference principle, first a grating of very fine lines is cast onto a cross-sectioned BGA at an elevated temperature (usually a polymer which cures around 100 degrees C), then the BGA is cooled, placed in a holding fixture, and a laser system is used to project a reference grid with the same line spacing onto the grating that was previously cast. Since the PBGA shrinks as it cools following casting, a series of interference fringes are formed when the reference grating is projected on the surface. Each fringe represents a fixed displacement (~500 nm for instance). By counting the fringes, one can determine how much movement occurred due to the cooling and the CTE can be computed. Figure 8.43 shows the typical fringe pattern obtained from a PBGA.

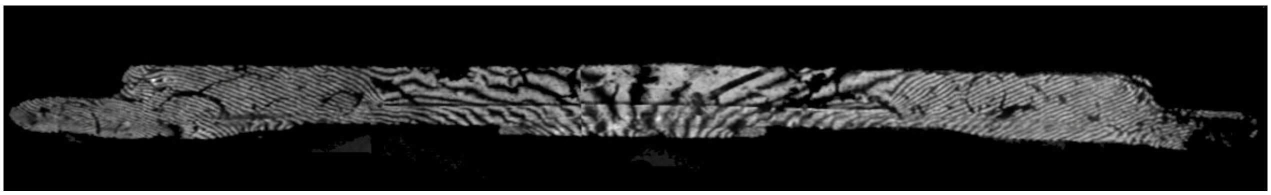
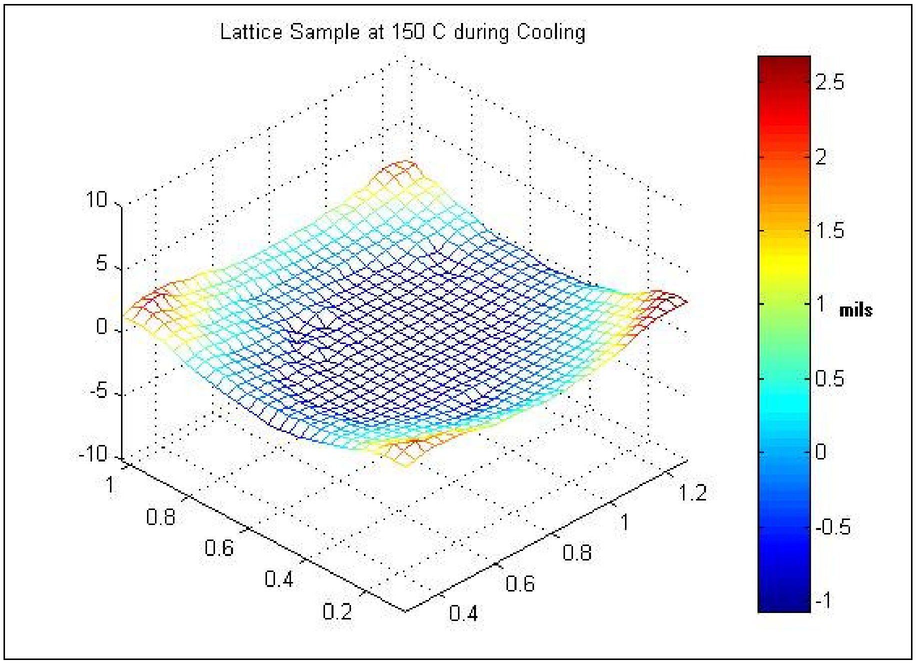


Figure 8.43 – Moiré' Interferometry fringes obtained from a typical PBGA.

In addition to measuring the CTE, BGA warpage can be measured using the Moiré' Interferometry principle utilizing shadows (e.g. Shadow Moiré'). To measure package warpage, first all the balls (or columns) are removed from the bottom of the package and then the surface is coated with a white coating (typically a high temperature paint). The BGA is now placed in an environmental chamber capable of heating the part up to solder reflow temperatures (~220 degrees C). The measurement is then obtained by placing a glass plate with etched grating lines a fixed distance over the sample. A light is projected at an angle downward through the grid which casts a shadow on the sample. A camera positioned directly above the sample records the image. If the surface of the sample is parallel to the plate, no fringes will form. If it is out of plane, interference fringes will be formed due to the interference between the plate grating and the shadow lines. Again by counting the fringes, one can determine the amount that the part has moved away from (or toward) the plate.

The measurement begins with the sample at room temperature, after which time it is heated to 220 degrees C and then cooled back down to room temperature. Measurements are taken at room temperature, 100, 150, 183, 200, and 220 degrees C during both the heating and cooling phases. The measurements are applied to a 3-D plot to show displacement across the part at particular temperatures. An example of the results obtained is shown in Figure 8.44. While reviewing warpage data, it is important to note the direction of curvature. In addition, PBGAs that do not return to their original shape after heating should be evaluated further to insure that the permanent deformations from the soldering process will not be detrimental to the long term reliability of the device.



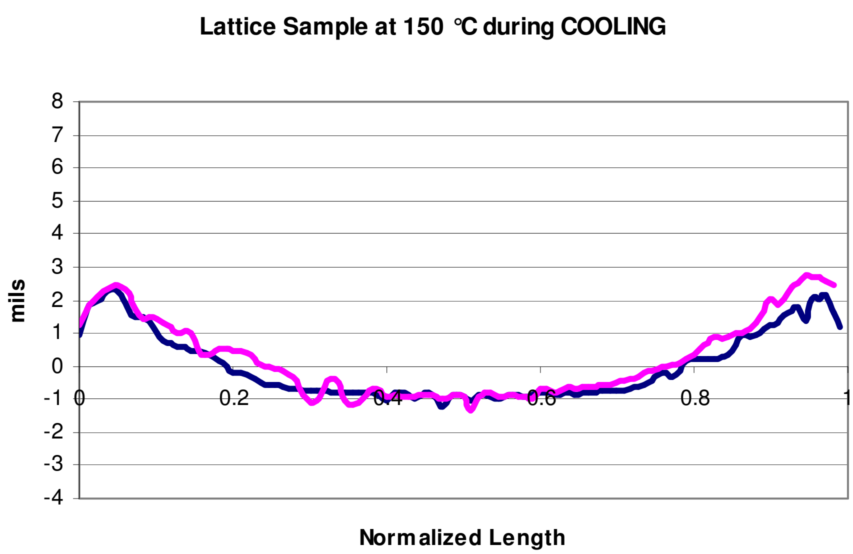


Figure 8.44 – Lattice 388 PBGA Warpage Measurements

(at 150 degrees C while cooling from 220 degrees C)

Another important factor to be considered during the assessment of a PBGA for use is the size and location of the die. As was highlighted in Figure 8.41, the die can result in a local reduction of CTE. Thus, the balls near the die corners and edges may fail earlier than expected. A summary of die size, CTE, and warpage for the BGAs evaluated is given in Table 8.17. Note that the local die effect is not a factor for the BGAs in this study. For instance, the 388 package style had redundant power and ground pins under the die and the balls adjacent to the die are not populated.

Table 8.17 – BGA Die Size, CTE and Warpage Summary

Description	Die Length (inch)	Die Width (inch)	CTE (ppm/C) (3)	Warpage (mils)(4)(5)
IBM 304 CCGA (1)	NA	NA	6	No warpage
IBM 625 CCGA (1)	NA	NA	6	No warpage
Amkor 432 sBGA	no die	no die	16	No warpage
Amkor 388 PBGA	no die	no die	15.6	6.70 convex
White Tech. 219 PBGA (2)	0.3270	0.3150	11.21	Not measured
Lattice 388 PBGA	0.3040	0.2650	16.2	9.75 concave
Motorola 360 CBGA	0.3252	0.2488	6 for Motorola	No warpage
Atmel-high CTE			12.3 for Atmel	
GSI 209 PBGA	0.4800	0.4250	10.1	3.01 concave
Galileo 388 PBGA	0.3720	0.3700	13.75	7.25 convex
AMD 64 PBGA	0.3236	0.2106	14.3	1.50 concave
Intel 64 PBGA	0.2590	0.2310	10.6	1.15 convex

Notes:

(1) Die size information not reported on ceramic parts (except Motorola PowerPC).

(2) Die size reported is for one die only. White part contains five separate semiconductors (see data sheet in Appendix A).

(3) CTE is taken across the entire width of the component. The PBGA measurements are preliminary measurements from one BGA in only one direction. CBGA CTEs were obtained from the supplier.

(4) Warpage is reported as worst case across range of temperatures from Room to 220 Celsius. The ceramic column and ball grid arrays were not measured but are assumed to have little or no warpage. Also the sBGA 432 was considered to have no warpage because of the thick Cu heat spreader.

(5) Warpage is reported as either concave or convex in relation to the ball-side of the component.

The fact remains that PBGA structures are very complex. To support the Georgia Tech finite element modeling efforts, the cross-sections of the Lattice 388 and the AMD 64

PBGAs were examined very carefully using optical and Scanning Electron Microscopy (SEM) to determine the thickness various features within the PBGA. Figure 8.45A, B, and C shows several cross-sectional views, as taken by SEM, of the AMD 64 and the Lattice 388 PBGAs, where thickness of solder mask, copper layers, glass-epoxy layers, die attach, die and over-molding can all be seen.

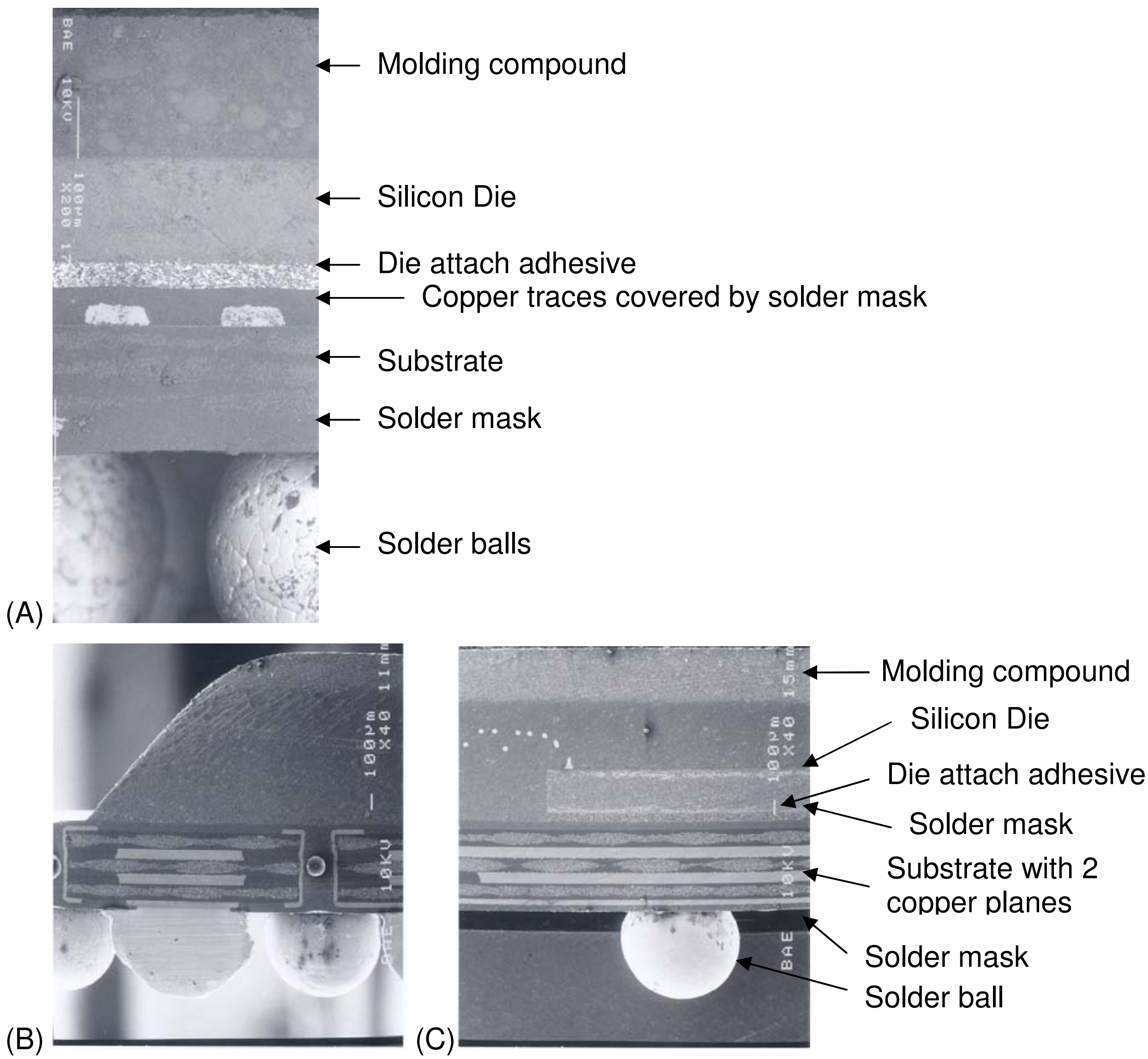


Figure 8.45 - AMD 64 (A) & Lattice 388 (B and C) PBGAs SEM Images

Section A is located in the middle of the AMD 64 through the die. Section B is located at the over-molding compound edge and section C is in the middle of the Lattice 388.

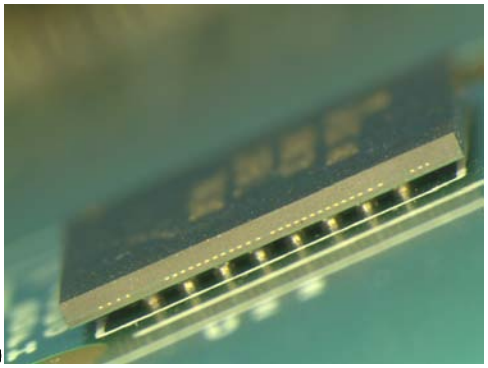
All of these measurements were fed into the details of the finite element models.

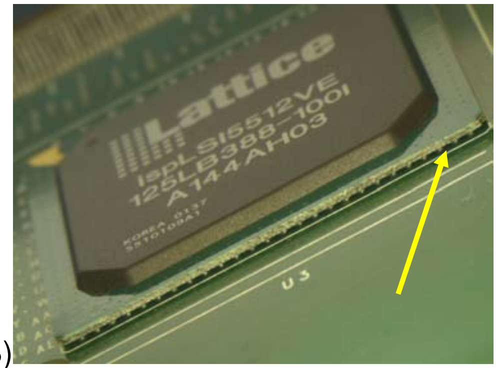
8.3.6 Georgia Tech Solder Fatigue Modeling

Parametric solder modeling is essential when attempting to predict the life of an electronic assembly subject to thermal cycling and vibratory loads. All BAE production programs are evaluated for solder fatigue life. The basic modeling approach is derived from the Englemair fatigue model for electronic components. The BAE model, like the Georgia Tech model, is used as a tool to correlate between two different sets of thermal cycle time histories. Typically, the failure data from a particular component/solder/module configuration subject, to accelerated thermal cycling are used to predict the life in the service environment (e.g. the number of hours/cycles the equipment is exposed to ground, take-off, cruise, landing, soak back, storage, etc.). Solder fatigue fractures by nature have some randomness and are typically reported in two parts, the mean number of cycles to failure, and the number of cycles for 1% of the population to fail. The mean cycles to failure represents the center of the failure distribution and the 1% failure probability gives an indication of the width of the failure distribution. The mean cycles to failure usually depends on the overall strain distribution within the solder, while the width of the distribution tends to be dependent upon the process variables such as solder volume, solder wetting, material properties, laminate thickness, etc.

Presently, there is limited accelerated thermal cycling and service experience with PBGAs in high reliability applications. In an effort to augment BAE's present understanding of the PBGA reliability, a detailed thermo mechanical finite element modeling (FEM) fatigue-modeling approach was pursued with Georgia Tech (Georgia Institute of Technology, Atlanta, GA. Dr. Suresh Sitaraman in the Mechanical Engineering Department). The FEM models were constructed to be very flexible such that the key parameters (like package size, thickness and number of balls) could be easily varied in the future. Prior to this pilot collaboration, Georgia Tech had already developed parametric thermo-mechanical fatigue models for the Amkor Super BGA (sBGA), CBGA, CCGA, and the Tessera uBGA on a PWB with a rigid bonded copper heat sink. During 2003, the BAE/GA Tech team chose to modify the CCGA FEM model to incorporate a silicon bonded aluminum heat sink and develop models for the AMD 64 and the Lattice 388 PBGAs.

The three components that were analyzed are shown in Figure 8.46. The 2003 analysis work would add two new BGA package types (over-molded and "molded and diced" PBGAs) to Georgia Tech's modeling library. Georgia Tech is integrating these parametric models into their Computer Aided Simulation of Packaging Reliability (CASPaR) tool, which is designed to give engineers a quick reliability assessment of a PWB assembly. To simplify the calculation for the user, the CASPaR tool utilizes a set of parametric equations, with Design Of Experiment (DOE) coefficients that are derived from the detailed FEM results, to compute the solder fatigue life. To determine the DOE coefficients, key parameters in the FEM are systematically evaluated over the expected ranges and the resulting strain energy is determined. For instance, the simplified fatigue model could be used to quickly compare different ceramic column grid array package sizes on a module and determine what the column height needs to be to meet the life requirements. The model would run very fast since there is no finite element code involved.

(A) 

(B) 

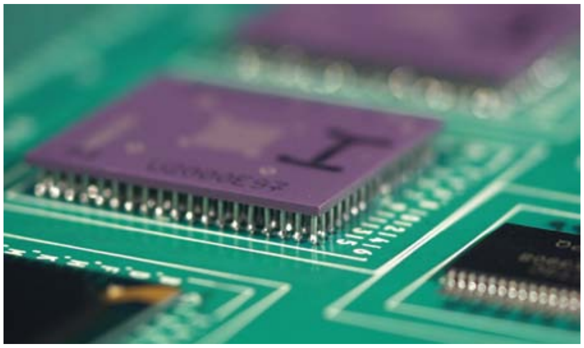
(C) 

Figure 8.46 – Photograph of two PBGA types and one CCGA soldered to a PWB.

(A) 64 pin molded and diced 1 mm pitch PBGA manufactured by AMD. Note that the molding is a uniform thickness over the entire device.

(B) 388 pin over-molded 1.27 mm pitch PBGA manufactured by Lattice. Note that the arrow indicates the corner balls that are joined to the portion of the BGA interconnect substrate not supported by the central over-molding. The unsupported BGA interconnect exhibits greater warpage than the interconnect covered by molding in center of the part.

(C) 304 pin Ceramic column grid array.

To determine the solder fatigue life, the finite element model was used to compute the accumulated plastic work through the thermal cycle. The accumulated plastic work is used as a damage metric to assess the solder joint fatigue behavior. Some amount of plastic work occurs each cycle as is shown in Figure 8.47. Once the plastic work is determined, the fatigue life is computed in two parts, first the number of cycles initial crack formation is determined, and the second the number of cycles for the crack to propagate through the ball is calculated.

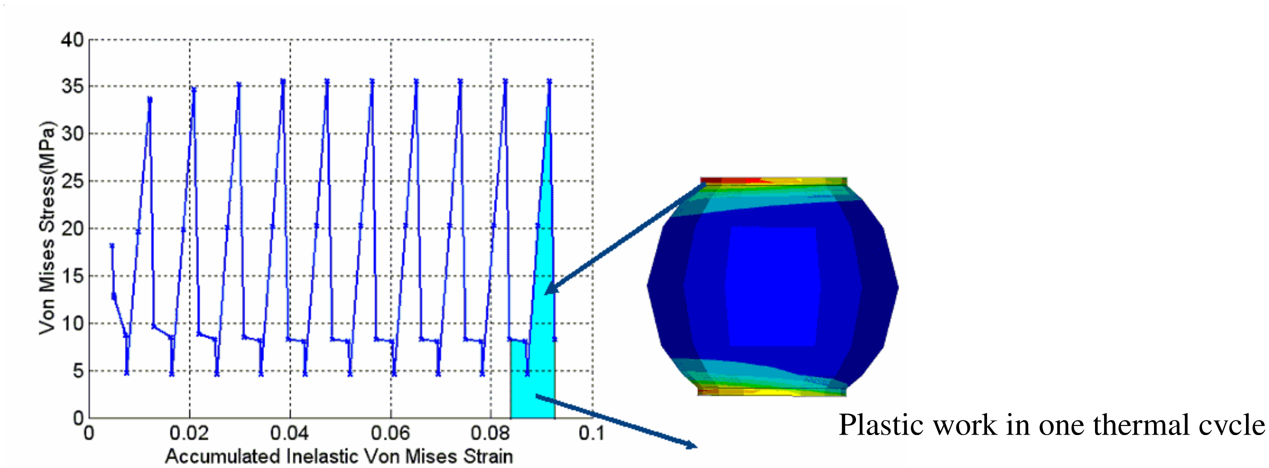


Figure 8.47 - von Mises stress vs. Accumulated inelastic von Mises strain for a typical element.

The results of the model predictions are given in Table 8.18. The GA Tech model for the 304 CCGA was in good agreement with the thermal cycling results given in the next section. Since the thermal cycling of the 2003 modules was delayed, the model for the 388 Lattice PBGA was compared with the 388 Daisy chain test part results. The agreement was particularly good considering the fact that the daisy chain part in thermal cycling had sub-optimal solder joints. In an effort to further improve the Lattice 388 model validation, the finite element model displacements were compared to Moiré' measurements of a module slice. The correlation was very good for the temperatures evaluated. The Moiré' results are summarized in Table 8.19 and a representative fringe field is shown in Figure 8.48.

Table 8.18 – Georgia Tech Modeling Results Summary

(cycles to failure, –55 to +95 degC, ½ hour thermal cycle ramps and dwells)

Device	Predicted N1% (cycles) for a range of distribution shape factors	Predicted N63.2% (cycles)	Actual first failure (cycles)	Actual N63%
304 CCGA	2075 to 5600	8514	2347	2500
Lattice 388 PBGA (Over-molded)	2186	4373	1370(1)	1450(1)
AMD 64 BGA (Molded and diced)	860 - 990	1416	NA (2)	NA (2)

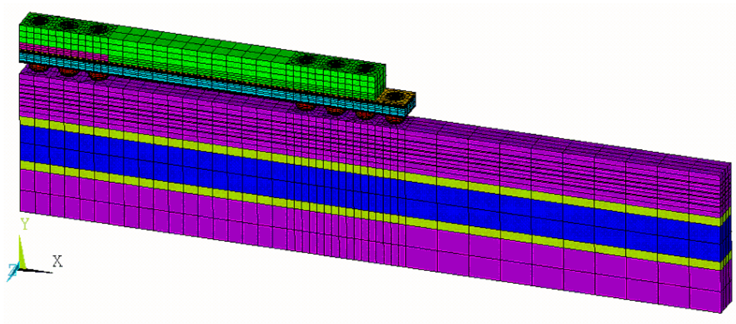
Note 1: The thermal cycling results for the 388 PBGA were used for the comparison because the 2003 module has accumulated only 100 thermal cycles.

Note 2: The experimental results for the AMD 64 are not available because the 2003 module has accumulated only 100 thermal cycles.

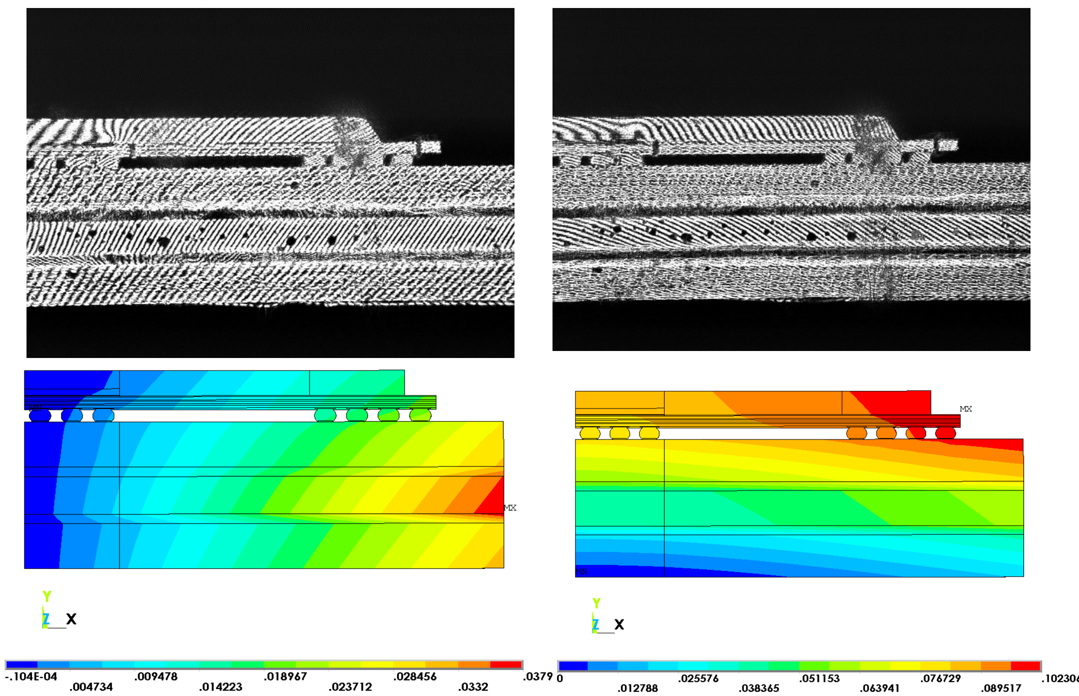
Table 8.19 – Moiré' Interferometry Finite Element Model Comparison

(Lattice 388 module)

Temperature	Fringe Pattern	Moiré Interferometry	Numerical Analysis	% Error
-25℃	U	0.014595	0.012098	17.1086
	V	0.010842	0.011728	-8.17192
100℃	U	0.02085	0.020883	-0.15827
	V	0.01668	0.015784	5.371703



(A) FEM Mesh of the general model used to for Moire' correlation



U Field

V Field

(B) Moire' Fringes and corresponding FEM displacement plots.

(U and V Moire' field fringes (upper) and U and V FEM displacements (lower) at 100°C)

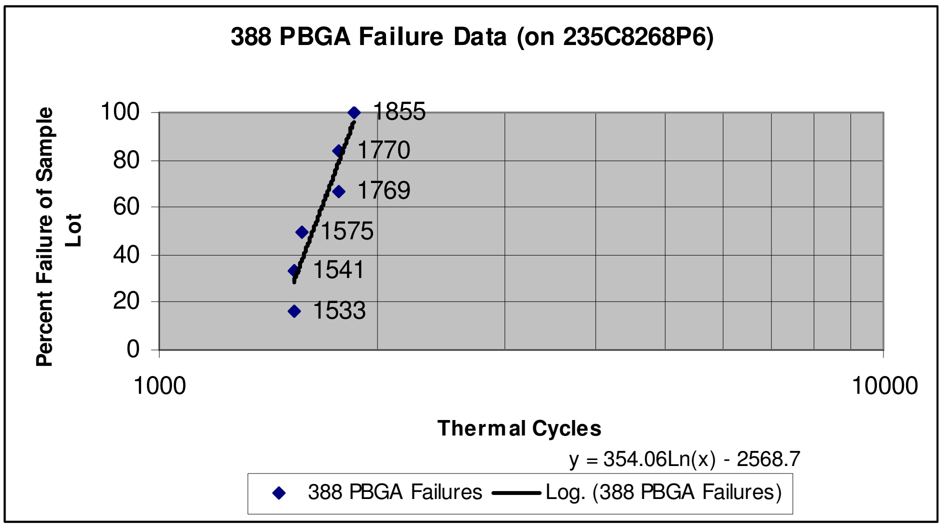
Figure 8.48 – Lattice 388 module section.

8.3.7 Thermal Cycling Results

Failure data was collected on a periodic basis for the modules discussed in this report. The daisy chain modules had accumulated 3200 cycles and the 2003 durability modules had 100 cycles as of the end of the project (2003 – but continuing as part of an internal

BAE project). A failed or "open" condition was considered when a component had at least a 200% greater resistance value than that observed after initial assembly. Failure data can be seen for the 388 PBGA (Figure 8.49), 625 CCGA (two variations, Figure 8.50), and the 304 CCGA (two variations, Figure 8.51). The results are not only segregated by part type, but by board variation as well.

The same 388 PBGA was used in two configurations, one on the 235C8268P6 Thermount board, and one on the 235C8750P1 GFG board. The data illustrates that the 388 PBGA reliability is greater when assembled to the 235C8268P6 Thermount assembly. This could be attributed to the overall lower CTE of the module assembly, which creates a closer match between the BGA, PWB and heat sink.



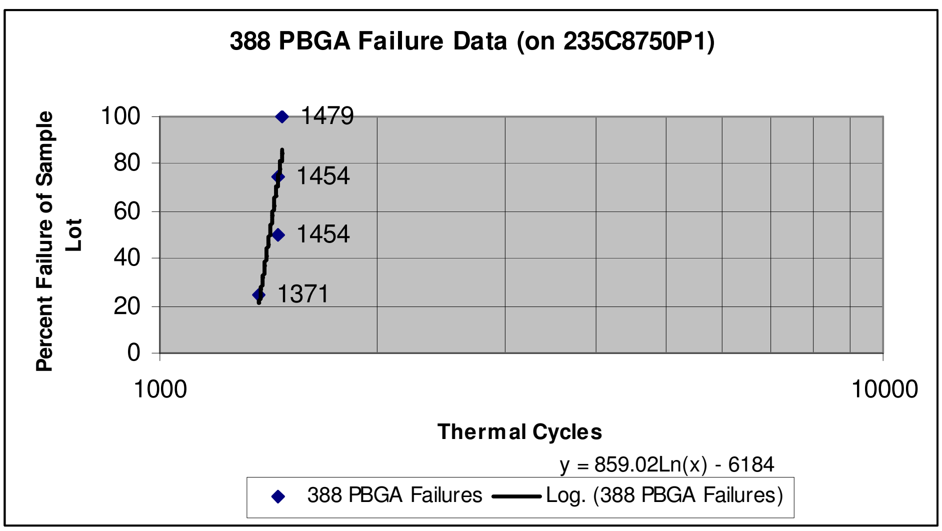
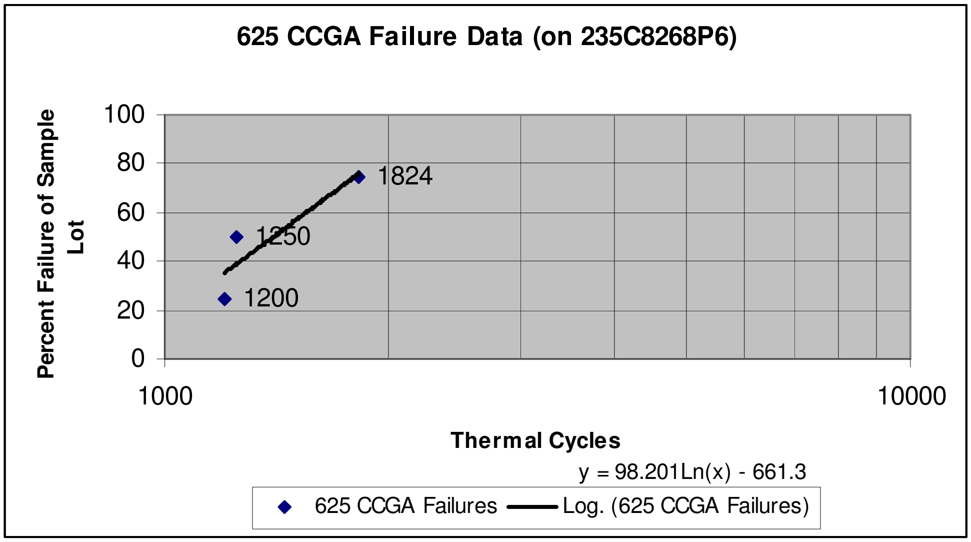


Figure 8.49 – 388 PBGA daisy chain thermal cycling results

Both the 304 CCGA and 625 CCGA were assembled to only one board configuration, that of the 235C8750P1 GFG board. The variation with these packages comes from the type of column attached to the parts. Both the 304 and 625 CCGAs come with a standard column (0.022" diameter, 0.087" high) and a spiral column (0.022" diameter, 0.100" high) which has a copper spiral coil that reinforces the column by winding along its outer perimeter from the package down to the solder joint. The results show that the spiral version of both parts is more robust since 1st failures of the spiral column version occur after that of the standard CCGA.



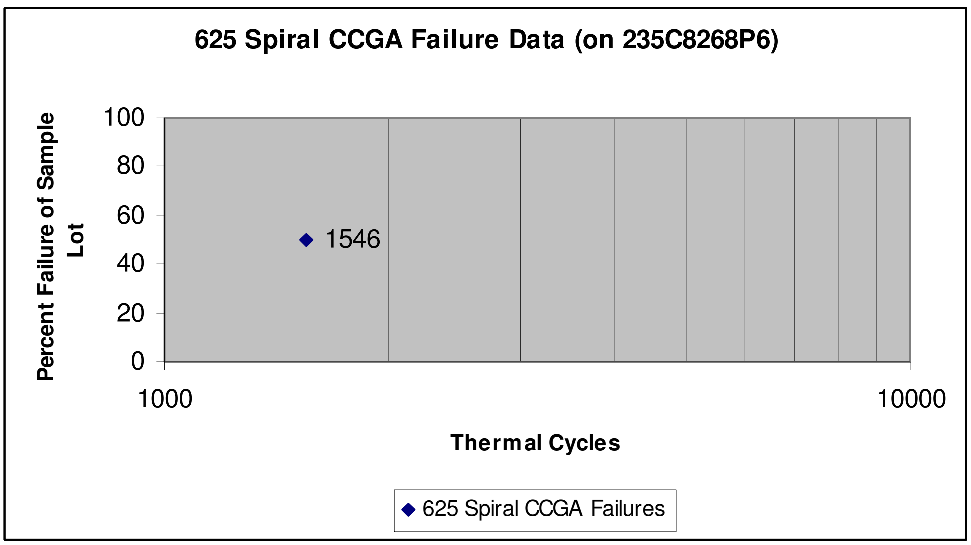


Figure 8.50 – 625 CCGA Daisy Chain Thermal Cycling Results

(IBM columns are shown above and spiral columns are shown below)

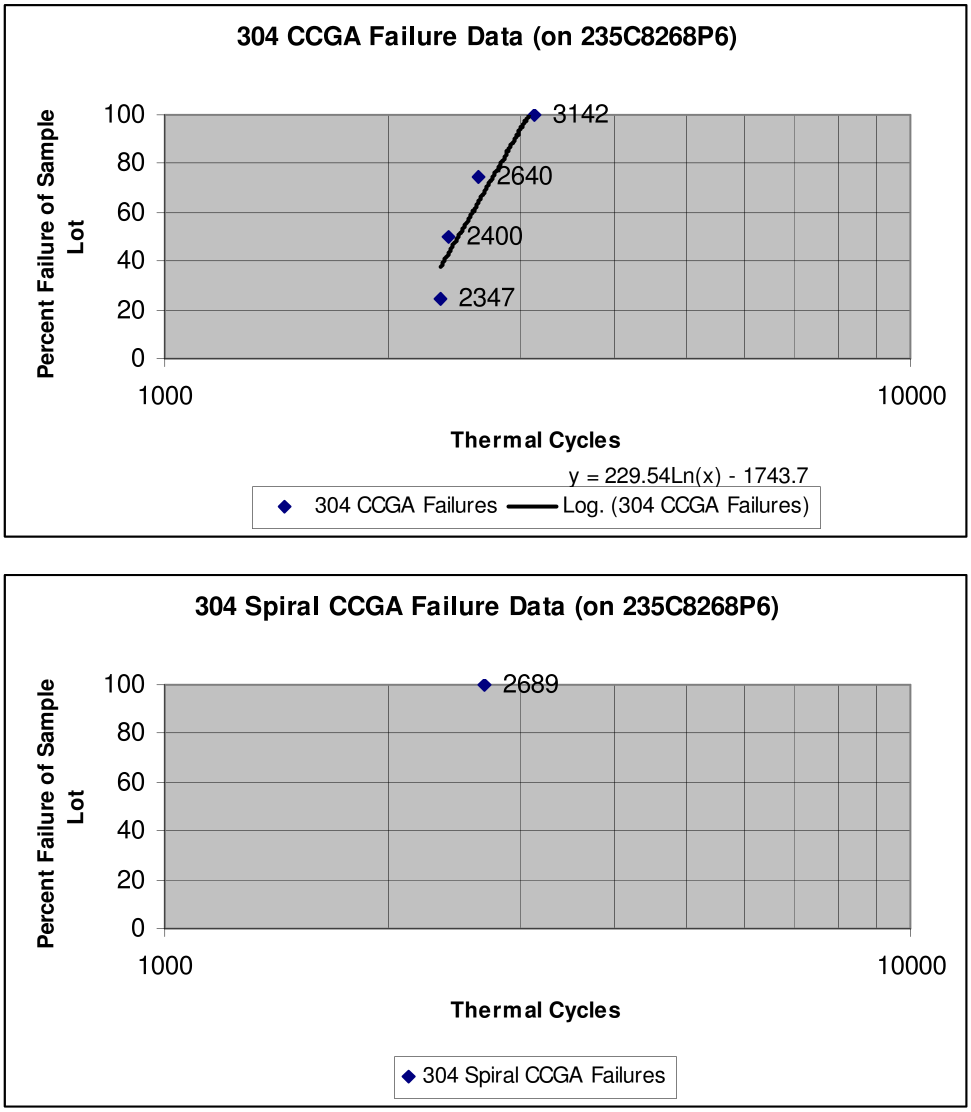


Figure 8.51 – 304 CCGA Daisy Chain Thermal Cycling Results

(IBM columns are shown above and spiral columns are shown below)

8.3.7.1 Physical Examination of failures:

The 90Pb/10Sn solder column grid arrays typically exhibited buckling, followed by a crack formation (Figure 8.52). The spiral column grid array did not buckle in this fashion. It is unclear if the life improvement observed for the spiral column grid arrays is due solely to the reinforcement of the columns with the spiral copper ribbon or is due to the increased column height (0.100 inch, verses 0.087 inch for the IBM columns).

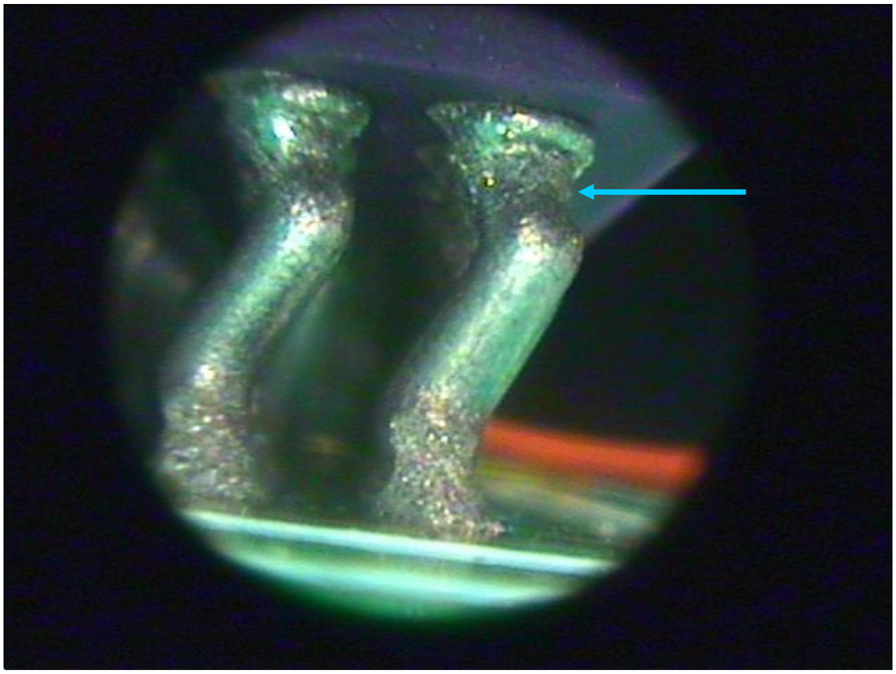


Figure 8.52 – Side view of a 304 CCGA @ 1400 cycles (no failures).

(Arrow shows the presence of a partial crack)

Note: Column deformation like this does not occur with the spiral column grid array type.

The physical examination focused on the Amkor 388 plastic ball grid array and the column grid arrays on the daisy chain module. Cross sectioning of one of the failed 388 daisy chained PBGAs was performed to determine the location of the fracture surface. The 388 PBGA section photos from U1 on PWB 235C8268P6 SN 0009 are shown in Figures 8.53 – 8.56. This particular BGA failed at 1770 cycles, however the cross sectioning occurred at approximately 2400 cycles. Therefore, fracture damage associated with these extra cycles is present in the photos. The images clearly illustrate lines of fracture along the BGA package pad and illustrate some problems with voiding within the solder volume.

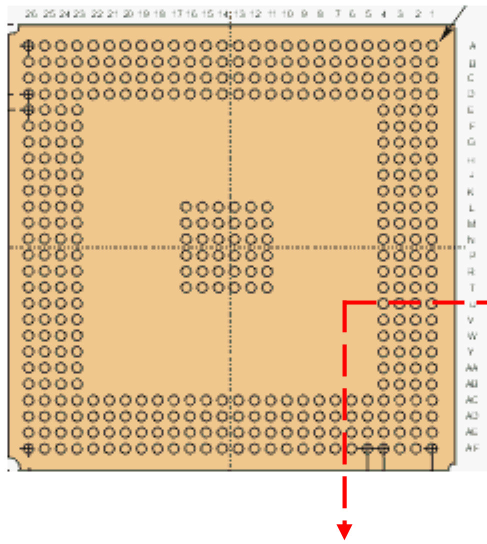


Figure 8.53 - 388 PBGA daisy chain part sectioning plane

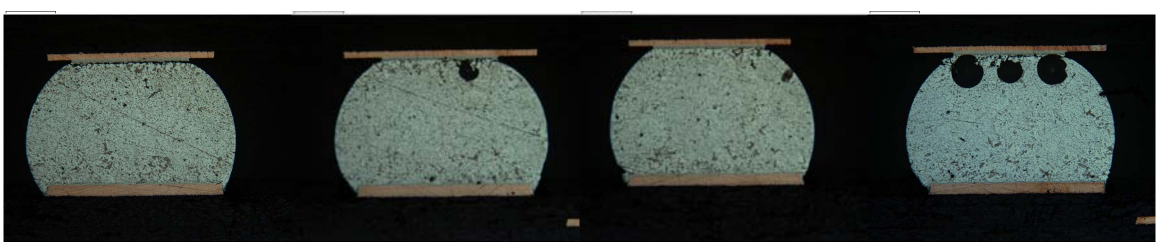


Figure 8.54 - 388 PBGA Daisy Chain Part Cross-Section

(From left to right the ball numbers are U4, U3, U2 and U1).

Note: U4 is completely fractured, U3 and U2 have a partial fractures and U1 is completely fractured.

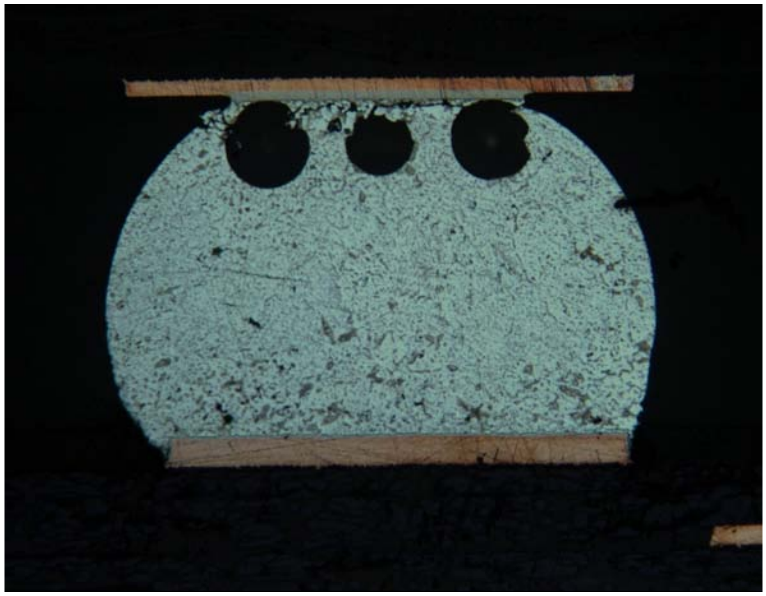


Figure 8.55 - 388 PBGA (Ball U1) Daisy Chain Part Cross-Section

Note: voids and fracture at PBGA pad interface

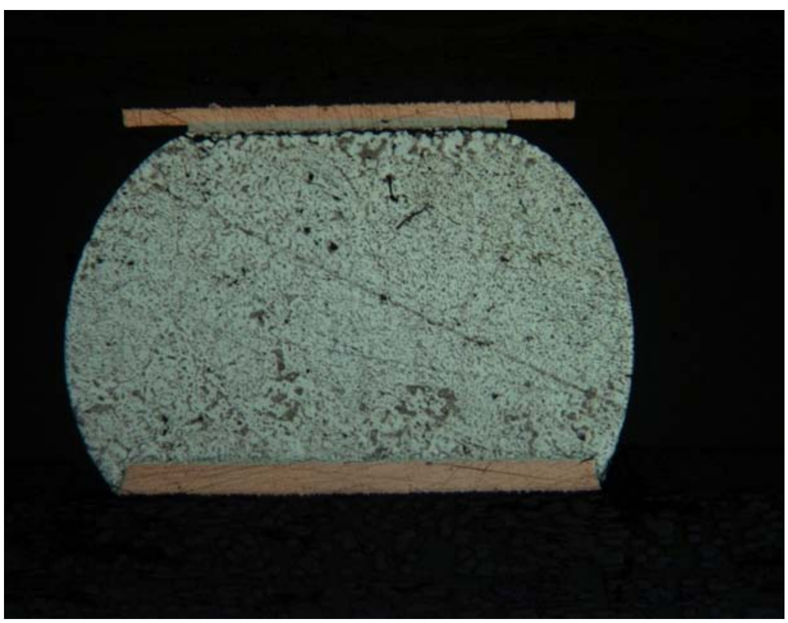


Figure 8.56 - 388 PBGA (Ball U4) Daisy Chain Part Cross-Section

Note: fracture at PBGA pad interface

8.3.8 BGA Solder Life Conclusions

The thermal cycling test results for the over-molded 388 PBGA and the ceramic column grid arrays are very encouraging. Even though the thermal cycling life for the PBGA 388s was good, it is expected that life would improve significantly if the PWB pad diameter were reduced to better match the package pad diameter.

As was seen from the 360 CBGA, it is important to insure that adequate solder paste volume is used during processing when non-reflowing package solder balls are used. Insufficient paste volume will result in a significant stress concentration in the solder joint that will lead to premature solder joint failures. Utilizing cross-section analysis as early as possible insures that the solder joint shape is optimal and facilitates the solder fatigue analysis by establishing an accurate “package to PWB” solder standoff height

A very important finding in this study was that not all plastic ball grid arrays are created equal. The PBGAs have a wide range of variation in material and internal construction features. As die size increases in the packages, the overall package CTE will decrease like the GSI 209 and the White 219 PBGAs. The CTE by itself is not necessarily a problem because the PWB/module materials can be selected to match the PBGA CTEs. The primary difficulty occurs when PBGA with a broad range of CTEs are used on a single module. Depending upon the size of the parts, it may no longer be possible to choose a module CTE such that all the parts have an acceptable solder joint life.

8.3.9 Potential Savings

The primary area of cost savings observed by a system/board designer and manufacturer would be through reduced costs for part or board qualification testing. Through the results of the model analysis and applying the knowledge base at BAE it was estimated that BAE would save through several approaches.

8.3.9.1 Procedures and Practices

The first cost savings approach resulting from participation in the POMTT program was the development of an obsolescence review methodology that has now been incorporated into BAE’s engineering procedures. The project resulted in the creation of several procedures that are currently being implemented on existing and future BAE programs such as F35 (JSF) and C17. Prior to POMTT, BAE’s obsolescence program was primarily reactive. Now, one of these procedures, BAE Engineering Procedure 102, now provides for a detailed parts obsolescence review during design and development. This procedure has identified risk parts prior to final parts selection, allowing them to avoid costly design changes, bridge buys, and other costs. Depending on the cost of change, there is a range of impact benefits to the programs.

Simple change
$3K per device

Moderate change
$10K per device

Complex change

$30K per device

Since the introduction of our new procedures, BAE estimates the total cost avoidance from the implementation of these new procedures to be = **$300K** per year.

8.3.9.2 <u>Physics of Failure Pilot Induced Design Changes</u>

The physics of failure work with BGAs also resulted in additions to BAE's design practices. Specifically, BAE has implemented a methodology where the BGA solder joint shape is examined early in the development phase of the program to insure that the PWB solder pad matches the BGA solder pad and that a uniform solder joint is obtained. This is a direct result of specific findings from the POMTT project that are being used to improve current production programs. For example:

It was found that insufficient solder paste was being applied to the ceramic BGAs on the C17, X45 and JSF programs. The design rules were updated and a procedure was implemented to more effectively communicate solder paste volume requirements from engineering to manufacturing.

Cross sectioning revealed that the PWB pad sizes were incorrect for a couple of parts. In this instance the root cause was determined to be a communication issue between the BGA supplier and the PWB design engineer.

BAE determined that plastic BGAs had a broad range of CTEs (10 to 16 ppm/C) and that detailed analysis was required to assess thermal cycling life when implementing these parts on a common PWB, and specifically the PWB material used on F35 (JSF) and C17 was changed to reduce the CTE mismatch of the assembly. This resulted in improved solder joint life.

The cost avoidance metrics for the above items are based on the cost of resolving a similar problem that went into test, undetected. This problem involved a purchased BGA packaged device that failed after assembly. The costs included the cost to analyze, determine root cause, coordinate with the supplier, implement corrective action and verify the corrective action. The labor cost of this event was $100K.

Based on this previous event, the estimate of annual occurrence and impact of other events is:

<u>Insufficient Solder</u>: 20 occurrences x 0.25 impact x $100K = $500K

<u>Incorrect Pad Designs</u>: 5 occurrences x 0.50 impact x $100K = $250K

<u>Total</u> = **$750K**

(Note: Cost Avoidance = Number of Occurrences x Impact x modeled cost)

8.3.9.3 CTE Mismatch Savings

The cost avoidance from the CTE mismatch is attributable to two specific programs. In this case a significant design effort was avoided, in addition to the labor cost model above.

In each case, the estimate of occurrence is 1. The program cost avoidance is based on the following formula: "Cost Avoidance = (Impact x modeled cost) + Redesign effort". To apply this for the two impacted programs result in:

C-17 Cost avoidance = (0.9 impact x $100K) + $300K =	$390K
F-35 Cost Avoidance = (0.6 impact x $100K) + $300K =	$360K
Total =	**$750K**

The total avoidance and savings therefore for BAE because of their participation in the POMTT program was $1.8M.

8.3.10 Pilot Summary, Conclusions, and Recommendations

The factors that drive parts obsolescence include high-growth of fast-paced markets such as computing devices, cell phones, and digital video. These markets and other new personal products will continue to drive the development of new parts technologies and shorter parts life cycles. Design methodologies for future military electronics suppliers must be capable of quick-turn designs, technology transparent/upgradeable, and with a support capability that more closely resembles commercial markets. With that, military products must be able to use commercial technologies, including Plastic Encapsulated Microcircuits (PEM).

8.3.10.1 Obsolescence Tolerant and Technology Transparent Designs

The ability to keep a design "frozen" (from a parts list perspective) still exists, with the use of lifetime buys and aftermarket sources to supply parts that have been discontinued by the original source. This was the predominant solution to obsolescence in a time in which the obsolete parts represented a small portion of the overall design. These designs were created from a series of building blocks, such as logic gates and op amps.

Digital designs progressed to using primarily microprocessor technology. Very high level integration allowed for major high-performance computing subsystems to be built from microprocessor designs. As the microprocessor market became driven by advanced personal computers, standards locked into that architecture. These architectures bring with them specialized the memory and peripheral devices. As improvements in microcircuit technology can provide for higher performance, software can remain compatible. A 3GHz PC can run the same software as the 300 MHz PC. However, the change in microprocessor brings with it a change in the entire peripheral chip set, including the memory.

In the same way, digital designer engineers of military electronics are faced with this tight coupling of a chip set. When the microprocessor becomes obsolete, the remaining chip set parts go with it. The cost of avoiding change has significantly increased as more parts become obsolete together. Lifetime buys for so many parts are cost prohibited and aftermarket suppliers are losing their ability to keep up with number of complex parts that go obsolete. Planning for design changes at proper intervals can bring the best overall value. Understanding supplier technology road maps and accounting for design upgrades reduces the cost of transition. There is a trend toward military electronics suppliers providing repair and replacement services for their fast-moving technology. This step has shifted the burden of support to the manufacturer. The manufacturer could replace a circuit card with an updated version that has been designed as a direct replacement.

This compares to returning a 1GHz PC to a repair facility after three years use and having it returned to you with a 3 GHz motherboard. Using the same programs, the changes in this computer would be transparent to the user.

8.3.10.2 <u>Use of Commercial Off-The-Shelf Parts</u>

The era of a strong military parts market that facilitated MIL-M-38510 and MIL-STD-883 also helped to bring together the US microcircuit industry. To participate in the military IC market, supplier's parts were characterized to the military specifications (slash sheets) and could therefore be compared on a level playing field.

The microcircuit industry, still developing, processed wafers that were graded as being either military temperature capable, or were passed down to the commercial product line. The military grade wafers were packaged, assembled, and tested. Those passing were allowed to be sold under the JAN qualified brand. Suppliers could also introduce products under their internal military equivalent processes. As users of these parts found failures, root cause analysis and feedback to the suppliers led to improvements in reliability. Later, statistical process control (SPC) techniques were employed by suppliers to improve processes, design rules and testing techniques. The result was higher yields of both military and commercial grades of microcircuits. With the drive to finer pitch geometries demanding more robust structures, the design rules for military and commercial merged into one. Wafer, and later assembly processes became highly automated, reducing error and process variability.

For many suppliers any wafer was military temperature capable. The industry had changed from the approach in which product was built, then tested or screened. By the early 1990's, the variability in wafers and wafer lots had greatly reduced and reliability had greatly increased. Research into plastic encapsulants led to improvement in moisture resistance and mechanical stability.

As suppliers such as Motorola exited the military products market, BAE SYSTEMS Controls (at that time Lockheed Martin Control Systems) began investigating the use of PEMs in military and commercial electronics systems. The findings indicated that many PEMs were suitable for this use, under specific controls. Internal procedures were developed to control sources of supply based on their plastic encapsulants, handling procedures, moisture sensitivity, internal qualification, and reliability monitoring. The sources themselves and their production were not controlled, but knowing what a supplier did was a factor in approving a part for use.

Internal storage and handling procedures were created to protect moisture sensitive PEM from being improperly exposed to moisture prior to solder to a circuit card. Extensive evaluations determined that once soldered, moisture sensitivity of the properly selected PEM did not impact the long-term reliability of the part.

To prove the part would function properly at extended temperatures, testing was performed. True to the industry claims, it was found the majority of these parts performed within specification limits, even at -55° C and +125° C. These concepts formed the basis of our processes for using PEMs in airborne electronic equipment. Evaluations of the potential for using selected PEMs in new designs without the extra testing are currently underway.

The failure analysis performed under this project supported the projections of PEM performance in extended environments. The study was based on PEM removals during repair of commercial jet engine controls. Few removals were found to be verified failures at the part level. The pattern of parts being removed, replaced, but not being verified suggested a few different theories for the cause of the fault in the system. The predominant theory was that the removed parts were solder joint related. BAE refocused their study to solder life of advanced packaging, including Ball Grid Arrays (BGA).

8.3.10.3 Advanced Packaging in Military Equipment Environments

Beyond understanding the electrical performance and package integrity of PEMs, is the challenge of dealing with the advanced high-density packaging. The commercial electronics industry successfully uses Ball Grid Array (BGA) packaging in many products. There is a difference in the coefficient of thermal expansion (CTE) of the Plastic BGA and the glass epoxy board material typically used. Across a relatively small operation temperature range, a BGA used in a commercial product can have long solder life. When exposed to the wide temperature range and more severe temperature cycles of airborne equipment, the solder life of these packages needs closer study. To properly qualify a BGA package for use, hundreds of temperature cycles must be performed. This process is costly and lengthy. In addition, each new BGA package would need to be qualified, since there was no confirmed approach to extrapolating the results to higher ball count packages.

Georgia Institute of Technology (Georgia Tech) developed computerized models of BGA solder joints. These models could be used to predict solder life under a proposed set of conditions. These conditions included the package type, size, number of balls, and construction. In addition, the models took into account the characteristics of the printed wiring board, including size, material, number of layers, and type of solder. The question was: “How well do the models correlate to actual solder life?” BAE SYSTEMS Controls partnered with Georgia Tech to perform a correlation study. The majority of the original scope of work is complete, showing a strong correlation of Georgia Tech models with BAE's temperature cycling tests. These tests are continuing under internal funding.

The result shows that computer modeling can be used to predict potential solder life issues. These issues can be addressed proactively, leading to a more robust mechanical design. In addition, portions of the qualification of a new package/board material can be reduced or eliminated. Procedures are in development that use the combination of computer modeling by Georgia Tech with actual temp cycling to complete the qualification process in less than half the normal amount of time.

8.3.10.4 Conclusions

The POMTT program has addressed many of the critical issues of obsolescence and parts management. The key issues of understanding part life cycles, planning for redesign, use of COTS parts, and replacement of parts from third party sources have been reviewed.

Improved methods of parts selection and obsolescence mitigation will help avoid significant cost and schedule impact to military programs.

With the reduction in suppliers of military-specific technologies, void must be filled in order for our systems capabilities to improve. Understanding COTS technologies and their life cycles will allow continued growth and better utilization of emerging technologies.

8.3.10.5 Recommendations

Through the study and review of new tools for managing obsolescence, areas for future study were uncovered:

There are potential savings from having a centralized obsolescence data source.

There is a need for standards for use of COTS in military electronics.

Continued studies of board, solder and heat sink materials to support large-scale advance packaging will be necessary to further the use of commercial parts in new airborne equipment designs.

8.4 TACMS / SLTA Pilot

Lockheed Martin Missiles and Fire Control – Dallas' System Level Test Automation (SLTA) pilot used the Rosetta System Level Description language and application tool (VectorGen™) to automatically generate test vectors and compare results with the existing TACMS 2000 design. Meetings were held with each of the tool vendors to determine their capabilities each tool/technology was assessed to see how they would integrate and enhance existing design and production processes and ongoing production program schedules. Production program personnel and enterprise design and production processes improvements leaders were contacted. These resulted in the Rosetta SLDL language and EDAptive's VectorGen™ software being selected for the pilot.

Preliminary work began early in the program to document M&FC-D's deficiencies and needs, and to establish the metrics and criteria for choosing a pilot program. The pilot began in August 2002 and was expected to have a 14-month duration. Improvements due to the application of the tool and process are: development of an unambiguous system level description capability, reduction in the amount of time for test vector generation, and possible synergy with other tools.

8.4.1 Overview

Rosetta, a System Level Design Language (SLDL), and VectorGen™, an automated test vector generation tool, are marketed as solutions to reduce hardware redesign and verification time. The System Level Test Automation (SLTA) pilot project was created to evaluate the possible insertion of Rosetta and VectorGen™ into established hardware production. This project would also determine the ease of use of these tools by an inexperienced redesign engineer.

The main approach in evaluating the usefulness of VectorGen™ was to write a Rosetta specification based on a component in a current LMMFC-D design, provide the specification as input to VectorGen™, and use the WAVES output from VectorGen™ to test genuine hardware. Although VectorGen™ and Rosetta didn't meet all of the expectations of this project, it was improved as the project progressed, it provided training on a new approach for M&FC-D designers, and could prove even more useful if additional changes are made to make it more viable in a hardware test environment.

8.4.2 Background

Rosetta provides a means of developing system-level modeling through the interactions of a multi-faceted model. Multiple facets are created to allow an entire system to be represented, highlighting the interactions between various design consideration parameters. Rosetta also provides a common language and common semantic environment for defining and integrating various component views to allow for sharing of design constraints and specifications across multiple disciplines.

VectorGen™ incorporates the system and test specification requirements written in Rosetta to produce generic test vectors in the WAVES format (see Figure 8.57). VectorGen™ uses the test specification as inputs into the system specifications and tests every possible input combination, attempting to highlight any possible hardware issues.

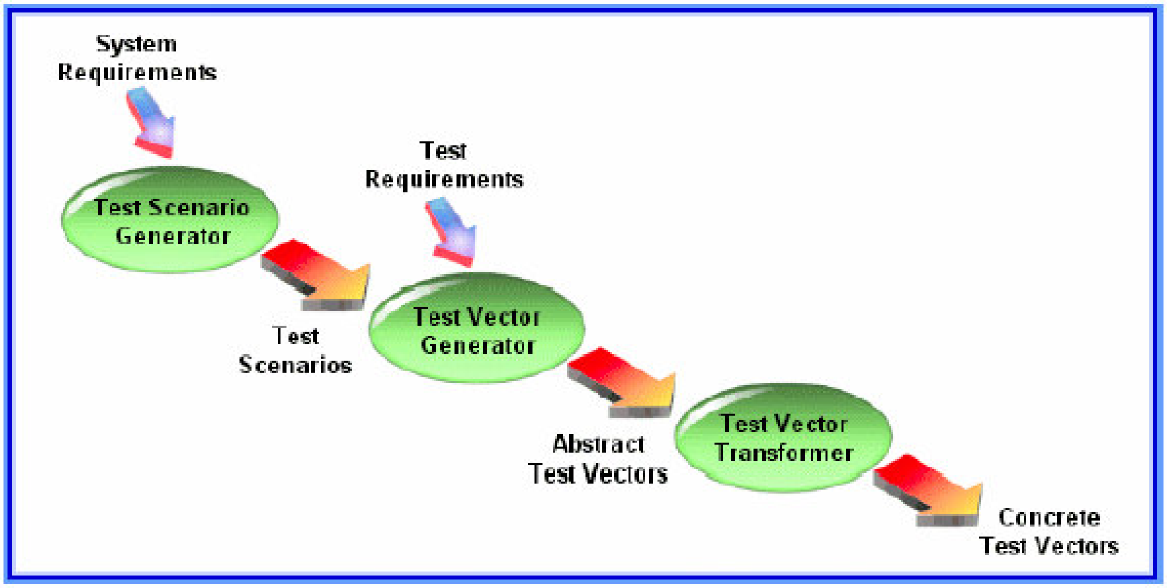


Figure 8.57 - The VectorGen™ Information Flow

Early in 2001 Dallas met with TRW and their subcontractors (University of Kansas and EDAptive) to evaluate the SLDL approach to system design and verification. By the end of the quarter, they had received and installed VectorGen ™, and were interested in its potential use in a pilot project.

Early on it was found that the complementary EPOI tool that Synopsys had developed (BPR) was not compatible with M&FC-D's current design environment. Dallas however, continued to assess the SLDL approach to see if they could define a pilot project that allowed them to use both EDAptive and Synopsys tools. The Synopsys BPR tool was completed and was available.

However, since the VectorGen™ tool from EDAptive had already been installed and some elements of an FPGA synthesizable specification were available from the PAC 3 program, they were converted from VHDL to SLDL. The SLDL specification was then used to successfully test the functionality of VectorGen™. After consultation with Dr's Perry Alexander and Praveen Chawla, parts of the spec were converted to Rosetta and VectorGen™ generated test vectors. A limitation was discovered in VectorGen™ that it could not yet process hierarchal specifications (specifications with referenced sub-specifications). It was decided to continue testing with both the Windows and UNIX versions of the software and determine if Rosetta specifications can be generated from behavioral models to eliminate the hierarchal limitation in the current version of VectorGen™. An improved version of VectorGen™ that processes hierarchal specifications is being developed and will be evaluated further when released.

Dallas continued to evaluate VectorGen™ and explore a possible pilot with PAC 3 using the SLDL approach for modeling, synthesis and testing of a new FPGA. They established Non Disclosure Agreements (NDAs) with EDAptive, VP Technologies, and Bluehead Software (Dr. Perry Alexander) to allow further exploration of pilot projects.

As a result, a Solaris version of VectorGen™ that was compatible with Dallas' Sun CAE servers was expected early in 2002 which should be more compatible with the Dallas engineering environment. It is possible that this could eliminate the hierarchal limitation in the current version of VectorGen™.

Unfortunately, in the first quarter of 2002 the PAC 3 program decided that it was not willing to release data for participation in an SLDL pilot so the POMTT team began looking for another target device on the LOCAAS and MLRS programs.

With the addition of Charles Blair to the effort, Dallas continued collecting design data on the CPUA components to determine if a component or groups of components on the CPUA card may be appropriate for consideration in an SLDL pilot. He also contacted EDAptive to have them provide a preliminary statement of work and ROM estimate to pursue a Virtual Prototype using the CPUA card. This approach required that VHDL specifications would have to be developed for several components. These components could then be used, however, in a shadow project to test SLDL tools while the on-going VHDL design project continues.

Additional discussions with TACMS 2K and a related HW/SW Codesign project under AMCOM AM3 direction were held. As a result, a circuit card in the Army TACMS Missile Guidance Computer (MGC) was selected for the potential pilot project.

The current electronic design process for this program includes a few steps that might be relevant for VectorGen's™' purposes. First, the process for verification that designs meet their specified requirements is somewhat inefficient. Upon receiving the requirements for a design, a "Requirements Verification Matrix" is developed containing all of the requirements, and the program engineers decide for each requirement which requirement verification method should be used (test, inspection, analysis, etc.). For those requirements which must be verified by test, it must be determined whether the test can be done at the board-level, or if it must be performed later at the "stack-level" (in which all of the circuit boards in the design are stacked together [in tactical configuration] for the test). In both situations, a new test is created in the relevant test software, and each circuit card that is manufactured is tested using this software. In this way, every time a circuit card completes its automated testing, verification of all "test-verified" requirements is completed.

The actual testing of MGC circuit cards takes place in two steps. The first portion of the testing consists of the board-level tests, which are somewhat limited. The first board-level test is an automated test performed using the HP3070. This test checks for "shorts" and "opens" between pins and performs loopback tests on each of the interfaces to verify that they are able to receive and transmit data. After the HP3070 test, a "Corelius" test is performed, which checks the ID codes of each of the devices in the Boundary Scan chain. The main problem with these board-level tests is that, for the most part, they only check for "passive" issues such as resistor values and part placement. These tests check very few of the *functions* of the parts on the circuit cards themselves. The functionality of the MGC's components is mostly verified at the "stack-level" functional test, in which all of the circuit cards are placed together. The downside of this is that the functionality of a circuit card cannot be determined without the presence of its sister cards.

VectorGen™ could theoretically make some of the processes above less difficult. First, if a Rosetta specification was written based on the requirements of the design, VectorGen could be used to automatically produce WAVES test vectors based on that specification. These test vectors could then be used to test the circuit cards, which would bypass the need for thinking of new tests for each requirement and entering them into the test software to verify requirements. Also, it's possible that VectorGen™ would allow for all of the requirements to be verified at the board level, which would mean that confidence that the circuit card meets its requirements could be attained without needing to wait for other boards for a "stack-level" test.

By the third Quarter of 2002 Dallas submitted a proposed plan for the System Level Test Automation (SLTA) pilot project to demonstrate the use of EDAptive's VectorGen™ tool on the TACMS program. Since TACMS 2000 program was redesigning their guidance electronics for the TACMS missile and was in the process of building test vectors for these new electronic cards and subsystems it seemed like a good match. One of the cards in the TACMS missile is the subsystem communications module (SCM).

The M&FC-D Team worked with the TACMS engineering team to collect both the VHDL description of one FPGA on the SCM board and the board's performance specifications. They planned to define the board's performance requirements in Rosetta to test the ability of VectorGen™ to cost effectively produce test vectors. This would be compared to the existing manual method of preparing test vectors.

In a telecon Dr. Perry Alexander, Univ. of Kansas, presented the status of Rosetta's expedited approval process at Accellera and the IEEE and indicated that the EDA community and the IEEE actively support SLDL as a needed and unique level of abstraction. Based on this, the pilot was formally approved in September 2002 and work began in defining and coordinating statements of work and support contracts for EDAptive and Bluehead Software.

8.4.3 <u>Pilot Approach</u>

The goal in this project was to determine whether the use of VectorGen™ and Rosetta made the requirements verification and hardware test processes any easier for the TACMS program. The initial approach was to select a design on which to focus for the project and write a Rosetta specification describing that design. Once this was done, VectorGen™ would be used to generate test vectors based on that specification. At this point test equipment would be used to perform an automated test on actual hardware, comparing its output to the WAVES output from VectorGen™. Then, the program engineers would evaluate the "VectorGen™ method" and compare it to their current methods for requirements verification and hardware test, focusing on the viability of

VectorGen™ for their purposes and the amount of time and money saved by replacing their current process with one incorporating VectorGen™.

A TACMS program engineer was consulted to determine which design should be used for the project. On his advice, the FPGA on the Army TACMS Missile Guidance Computer (MGC) Subsystem Communications Module (SCM) was chosen (This was a design on which the engineer had previously worked.) A Rosetta specification was then written using the FPGA's VHDL code as a baseline.

8.4.4 <u>Process</u>

A technical interchange telecon was held with EDAptive to coordinate efforts and EDAptive stated their concern that the skills necessary for developing specifications in Rosetta and running VectorGen™ were critical and that, without the right skills, the pilot could be risky. M&FC-D stated that the objective of the pilot was for Lockheed engineers to learn how to use Rosetta and the VectorGen™ tool rather than for Lockheed Martin to hire EDAptive to complete the pilot. If needed, subcontract support would be expanded as needed.

Rosetta documentation was downloaded and, to support the start of the SLTA Pilot, Dr. Alexander agreed to conduct a tutorial on Rosetta and VectorGen™. In the first quarter of 2003 Trey Fixico joined the POMTT team to lead the SLTA pilot as the result of his familiarization and initial efforts on the pilot. A contract was finalized with EDAptive and the University of Kansas (UK) for Rosetta training, and a one-year VectorGen™ license was also procured. Initial Rosetta files for the TACMS 2000 SCM card were prepared and forwarded to EDAptive for review prior to the training next quarter.

Trey Fixico reviewed both the VHDL description of the FPGA on the SCM board and the board's performance specifications and began converting these to Rosetta. In November the team met with Design Lead Chuck Reusnow and Charles Blair to discuss the status of the effort. Chuck suggested the team look at higher-level card verification requirements. He further recommended we coordinate the effort with the Dallas Hardware/Software Co-Design team since they were also working on the TACMS design. They proved to be very helpful in collecting further information on functions performed by the card and on interfaces between the card and other subsystems.

Around this time, EDAptive sent a revised VectorGen™ evaluation license agreement and price list. Unexpectedly, the price of the evaluation license had increased from "free" to $25k per year. Discussions were held with EDAptive who indicated that it was necessary to begin charging for licenses so that they could comply with their University of Kansas licensing agreements. Therefore, a one-year license was procured for VectorGen™

Dennis Basara at the Lockheed Martin EPI Center asked about the relationship between SLDL and UML development efforts. Dr. Alexander indicated that the two languages are using quite different approaches but have similar objectives for user communities. SLDL is focused on declarative descriptions of requirements and constraints with features that facilitate customized interfaces to the tools within different disciplines while UML focuses more on an executable, object-oriented approach. SLDL is more hardware oriented while UML is more software oriented.

8.4.1.1 Software/Design Approach Issues

Dallas continued expanding the Rosetta files for the SLTA Pilot. Trey also corrected the SCM DIO code by iteratively using the VectorGen™ compiler. He then tested his revised code with VectorGen™. The system seemed to work but a few additional issues needed further clarification. These were forwarded to EDAptive. Trey also began creating Rosetta state-based examples for the Asynchronous Clock facet and a FIFO facet to further test VectorGen™. Then Trey made plans to expand the DIO code to include reset and timing. As a result a question emerged concerning the extraction of a section of variables from a sequence. This is similar to a previous question answered by Dr. Alexander; i.e., how to extract a group of bits from a bitvector like bits 1-8 of an 11-bit wide bitvector. Since VectorGen™ did not recognize the syntax suggested by Dr. Alexander, Trey needed to know if this was something that could be expected in future VectorGen™ releases.

Another question that arose as part of the testing addressed the syntax for updating a single sequence position in the state-based domain. Trey needed to update the 9th position in an 11-bit bitvector. In the state-based domain, an update is accomplished with a tick (‘) mark. In any domain, to identify a single sequence position, the position number is called after the sequence name; i.e., A(9). The VectorGen™ compiler rejected this approach, but by changing the calling order of the variables, the compiler accepted the syntax. EDAptive was requested to review this issue because it was possible that the compiler didn’t have appropriate rules to correctly handle the syntax.

Finally, to produce a clock, Trey needed the timing facets to run continuously while creating test vectors. Since the timing facets are included as a subset of the EUC port facet, EDAptive was asked to see if VectorGen™ would automatically run the facets continuously. EDAptive replied that the current version of VectorGen™ did not support the expected method for extracting the middle bits in a bitvector. However, multiple single bit extractions can be used. VectorGen™ does support the continuous-running clock facet, but further clarification was requested.

While defining the timing functions, Trey found that the current version of VectorGen™ restricts parameter transfers between facets. This was presented to EDAptive. In a telecom with Northrop-Grumman, Northrop reviewed their approach to passing parameters between facets. Northrop used an unaltered version of VectorGen™ and didn’t have any custom interface programs to help their VectorGen™ program. They then provided sections of their Rosetta code for Lockheed Martin to examine and offered further discussions with the engineer who defined their Rosetta files.

The Northrop-Grumman files were examined to see how they used multiple nested “if” loops and to explore their approach for “requirements” facets in VectorGen™. Based upon these discussions, Trey generated more code and VectorGen™ recognized the syntax used to pass parameters, but the places the passed values should have been visible in were open. A question was sent to EDAptive to determine if the Alpha version of VectorGen™ supported structured Rosetta and EDAptive responded that the Alpha version did not.

By the third quarter 2003 Dallas found that the process of developing specifications and test vectors was a significant improvement compared to their legacy processes. At the same time, Dallas received Northrop-Grumman's Rosetta files and examined their code. It was determined that Northrop had not achieved parameter passing between facets. Instead Northrop took the outputs from one facet and hard coded the outputs as inputs into another facet. Using this technique, VectorGen™ produced the required test vectors but not in a single pass.

Once that was confirmed, the team continued developing the Rosetta code and, by the end of May, had completed the Serial_EUC facet of the TACMS 2K SCM card. They then began defining the parameters and structure of the FIFO facet. Discussions with EDAptive suggested ways to work around the VectorGen™ structural issues and provided examples of ways to use Rosetta by "flattening" the code to eliminate the need for facet-to-facet parameter transfer. This "flattening" of the code required that the secondary code be inserted into the primary code with some specific variable name formats.

In June, work continued on defining the parameters and structure of the rather complicated FIFO facet. The FIFO facet interfaces to an external RAM on the SCM card and multiple VHDL modules. Thus, the data and timing of passed parameters affect multiple angles of the asynchronous port. It was quite time consuming to trace the path and timing of data through the facets.

Next was the VectorGen™ evaluation of the TX_cnvrt module and discovered some minor modifications in the code were needed. After the changes were made, VectorGen™ compiled the TX_cnvrt file. However, when VectorGen™ tried to evaluate the code, additional errors occurred. Some were due to syntax changes during the VectorGen™ upgrade and some were undetermined.

The syntax issues were corrected easily and the code compiled and VectorGen™ created a "Scenarios" file, which showed that VectorGen™ accepted the individual lines of code. VectorGen™ did not show any errors in its Error Log. However in the Output Log, VectorGen™ indicated an "Exception". A previous error was traced to the version of the Rosetta parser implemented in VectorGen™. Corrections were defined and EDAptive updated VectorGen™ to correct the issue.

EDAptive provided an update to VectorGen™ files to correct the "Exception" error but testing also revealed another issue. It was found that when nested "IF..ELSE" loops don't include all their parameters in the parameter list, VectorGen™ produces unanticipated results. This was a major issue since some of the SCM code iteratively updates bits are not predefined and cannot be included in the parameter list. When those bits are excluded, VectorGen™ executes but not as needed. EDAptive began exploring this issue and recommended a two-week delay in the release of the next version of VectorGen™ to allow additional improvements to be incorporated.

EDAptive-recommended changes were also made to the TACMS Rosetta specifications. The changes included adjusting the syntax of bitvectors from [0;;0;;0] to [0, 0, 0], adding a new "time = 20" attribute to output vectors and changing the IF, THEN statements on bits from IF(a=1) to IF(%(a)). VectorGen™ also did not support Rosetta's capability of specifying a single bit within a bitvector. Rather than being able to check a single bit with an IF, THEN expression, such as IF(bitvect(2)=1), single bits were created for each bit in each 16-bit word of interest.

A new version of VectorGen™ was received and installed that corrected the processing of parameters within nested IF, THEN expressions. The "Flattener" program scans a Rosetta specification and checks for USE clauses and signifies that the USE file is a dependent file. Then "Flattener" performs some syntax modifications and creates a pre-processed Rosetta specification for input into VectorGen™. Test cases were set up to assess the validity of this approach.

A test case of the updated version of VectorGen™ and the "Flattener" program revealed that, after 2 hours, the run was stopped because it looked as if the computer had locked up. 75% of the code was then deleted to see if problems with the code caused VectorGen™ to fail. The shortened test case produced a "vectors.xml" output file but produced no "waves" file (even though it reported no errors). The output file was 1925 pages in length in XML format and 1790 pages when opened with MSWord. The time to produce the output file was around 30-40 minutes; therefore it seemed that VectorGen™ had probably been processing properly. Because of the length of the test A code and its inputs, VectorGen™ required a longer time than expected to produce reports.

After review of the shortened test case it was found that most of the output file was null, likely because of the multiple inputs and the specific order the inputs need to be set to receive output data. Also, some of the significant outputs were duplicates, because some inputs, significant to one section of code, were "don't cares" in another section. The pages with significant data only numbered to about 250 pages. Therefore, EDAptive was again contacted to discuss 1) why no "waves" file was produced and 2) how to reduce the amount of time and computer resources to run VectorGen™. If the evaluation time can't be reduced significantly, then "Flattening" the code for multiple facets will just create longer, more complex code with huge output files.

Once convinced that VectorGen™ was processing without errors, the initial test was re-run and VectorGen™ ran continuously for approximately 80 hours. It produced a 2.64GB TX_cnvrt_Vectors.xml file but again, no "waves" file was created. Also, opening the 2.64 GB file was problematic because there was not enough RAM to open the file. EDAptive confirmed that the cause of the large output file was the high number of inputs but did not understand why no "waves" file was created since no errors were noted in the "Log" window. These were sent to EDAptive for examination. They ran tests on the code and were able to generate appropriate "waves" test vectors from the abstract vectors, when the two processes were run in separate steps. However, they found that when VectorGen™ tries to generate a "waves" file immediately following the creation of abstract vectors, it produces an "out of bounds" memory error.

8.4.4.2 Process Issues

The process used for the pilot was set to create Rosetta code incorporating as much of the VHDL TX to RX loop-back within one facet. Care had to be taken when writing the code, because creating too large of a Rosetta file could cause many problems, such as difficulty with timing, large output files and difficulty in trouble-shooting. One of the first attempts at creating the TX to RX loop resulted in a WAVES output file size of 2.6 GB, but only about half of the file was usable data, because of Rosetta running through every combination, most of the outputs were zeros. This occurred because of the number of inputs into the Rosetta file. The facet was run with all of the original VHDL inputs set as inputs into the Rosetta code, but it was determined that if most of the inputs were set as constants in the Rosetta code, then the inputs into VectorGen™ could be reduced, reducing the output file size. Working with the Beta version of VectorGen™ resulted in many issues to work through to get the Rosetta facets to operate in a manor that emulated the VHDL code. Some of the issues were: no clock capability, no exclusive-or capability, an ambiguous “next” state capability and no multiple if-then loop capability. The clock capability occurred from the manor that VectorGen™ executes the input specifications. In the input file, if a variable is set as a bit, VectorGen™ only allows the bit to be set as a 0 then a 1 for each set of inputs.

There is no way to have VectorGen™ continuously operate a 0-1 clock with out doubling the number of input loops or have multiple 0-1 clocks run for each input set. To resolve this issue, an integer was designated as the clock and allowed to step up from 1-22 for each input set. The exclusive-or capability affected the parity bit calculations. The parity bit is calculated by “exclusive-oring” every bit together. This issue was resolved by separating the exclusive-or calculations into if-then statements. Multiple if-then statements were looped together to simulate the exclusive-or calculations. This also was the source of error in the data achieved from the hardware test of SCM module. Because a logic error was coded into the exclusive-or if-then loops, some of the parity bit calculations from the hardware tests were wrong. When the first five bits are 1’s, the parity should be passed though as a 1, but in the Rosetta code the parity calculated at that point was given a value of 0. The “next” state designation was inconsistently used and did not operate in a similar manner to other code languages. This issue was resolved by trial and error, along with multiple emails back and forth with EDAptive. A critical error when initially writing the Rosetta code was not having the ability to write multiple if-then loops. Multiple if-then loops are a fundamental portion of writing code and VectorGen™ didn’t have the capability to support them. They were used to emulate the case statements for calculating parity, to emulate the multi conditional if-then statement and allow the enable and clock integer to operate. EDAptive helped greatly with incorporating critical programming issues into the VectorGen™ software issues were discovered and brought to their attention. Along with fixing critical items as the issues surfaced, EDAptive is finishing the next build of VectorGen™, which is reported to resolve most of the programming issues discovered in the SLTA Pilot Project.

After learning how VectorGen™ operates and becoming familiar with the method used to develop Rosetta facets, a Rosetta specification was developed that incorporated most of the TX and RX operation used by the SCM Asynchronous Serial Port. The code in its' current state is around 1200 lines long and would take an estimated 4-6 weeks of work to create the Rosetta specifications and produce WAVES results. The code only uses the clock and data as inputs, many of the signals that are inputs within the VHDL code are hard-coded as constants, to help reduce the output size. The output WAVES file was reduced to approximately 287kb file, with 256 separate outputs spread over 5888 lines. Even with the size reducing techniques incorporated into the Rosetta specification, the current licensed version wasn't able to produce the WAVES output file. The current licensed version of VectorGen™ has memory sharing issues with the method VectorGen™ transfers the outputs from Vectors to WAVES format. The next build of VectorGen™ was the version EDAptive used to generate the WAVES file, helping prove that the next build of VectorGen™ resolved the memory sharing issues.

Once the WAVES test vectors were generated, they could be used to test an actual SCM. The SCM to be tested was stacked with its sister boards (a Guidance Processor and Power Supply Board) and connected to a 28V power supply. The new firmware was loaded to the SCM board from a desktop PC. An oscilloscope was then connected to the "Asynchronous Spare" signal on the FPGA so that the output of the ASM could be monitored. An HP Probe was also connected to the stack, so that the input of the ASM could be controlled.

At this point, random bytes were chosen and manually inserted into the "Asynchronous Spare Transmit Immediate" register via the HP Probe. This data would then pass through the ASM, which was monitored by the oscilloscope. The oscilloscope output for each byte was captured and verified by comparing to the expected output of the TX WAVES file. Ten recorded bytes were verified, along with other bytes that weren't recorded.

8.4.5 <u>Data</u>

The relevant data for this experiment can be found in Table 8.20. "WAVES Input" is the random byte selected for test. "Reversed WAVES Input" is the randomly selected byte reversed. "Probe Input" is the actual value written to the "Transmit Immediate" register.

Table 8.20 - Data Obtained from SCM Test

WAVES Input	Reversed WAVES Input	Probe Input	Expected WAVES Output	Measured Output	Output Data	Parity
00000000	00000000	00000000	0100000000001	00000000011	00000000	1
11111111	11111111	FF000000	0101111111101	01111111111	11111111	1*
01010101	10101010	AA000000	0100101010101	00101010111	01010101	1
10101010	01010101	55000000	0101010101001	01010101011	10101010	1*
10010110	01101001	69000000	0101001011011	01001011011	10010110	1
11101000	00010111	17000000	0101110100001	01110100011	11101000	1*
00111110	01111100	7C000000	0100011111001	00011111001	00111110	0
10000001	10000001	81000000	0101000000111	01000000111	10000001	1
11001100	00110011	33000000	0101100110011	01100110011	11001100	1
00011100	00111000	38000000	0100001110001	00001110001	00011100	0

To obtain this value, the "Reversed WAVES input" was converted to hexadecimal format. "Expected WAVES Output" is the expected output obtained from the TX WAVES file. "Measured Output" is the actual output seen on the oscilloscope. The output format for this signal can be seen below:

Bit 1: Start bit (0)
Bits 2-9: Data
Bit 10: Parity
Bit 11: Stop bit (1)

"Output Data" and "Parity" are the data and parity bits stripped out of the "Measured Output." The "Parity" bits with an asterisk indicate the parity bits which were miscalculated due to logic errors within the Rosetta code.

An example of the oscilloscope printout for a sample WAVES Input can be found below, in Figure 8.58. Because the "Asynchronous Spare Transmit Immediate" register contains 32 bits, the data contained in the register was sent through the ASM in four 8-bit bursts. These four bursts can be seen in the printout, in which the first burst contains the WAVES input, and the other three bursts contain "0"'s.

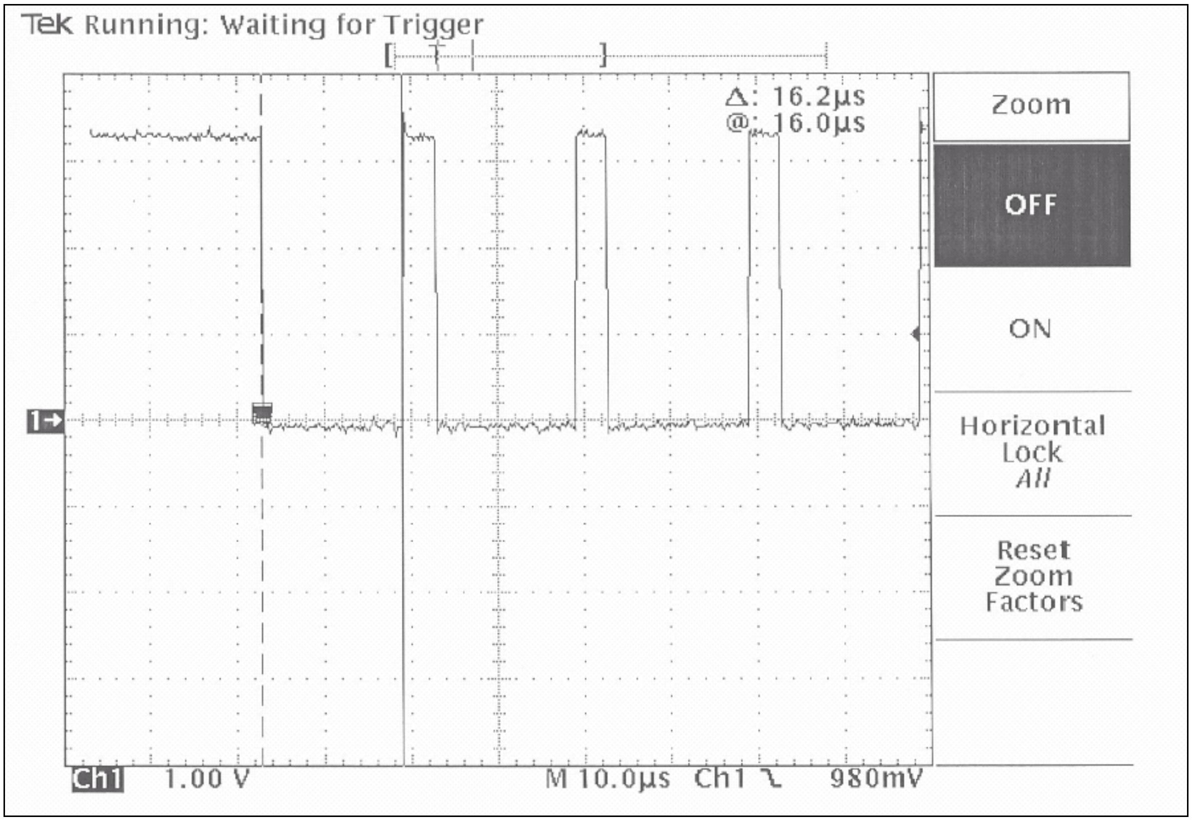


Figure 8.58 - Oscilloscope Output for WAVES Input 00000000

8.4.6 Analysis

There were a couple of unexpected issues that caused the expected WAVES output to differ from the output measured on the oscilloscope. The most obvious discrepancy was that before every byte was transmitted, a "0-1" was not present that was expected at the beginning of each transmission. In the WAVES output, it was coded that a "0-1-0" combination would precede every output byte. This was a result of the Rosetta code being programmed to start in the "zero" state. However, it was determined that the VHDL output starts in the second state, so the "0" before each byte is actually the third character of the "0-1-0" sequence, and the "0-1" is left off. Second, as mentioned earlier, the parity bit was miscalculated in some instances. In examining the Rosetta specification, it was discovered that there was a mistake in at least one of the XOR calculations used to determine the parity for each possible input. Unfortunately, there was not enough time left in the project to alter the Rosetta specification to test these corrective actions.

Apart from these two differences, the data measured on the oscilloscope matched the VectorGen™ output perfectly. In none of the testing was there a discrepancy that could be attributed to VectorGen™ not providing the correct output for the Rosetta specification that was provided.

8.4.7 Recommendations and Findings

Although the project focused on a small part of a design and was further limited by not being able to perform an automated test using WAVES, some statements can be made about the potential value of VectorGen™ to future design programs based on our experience with this project. Unfortunately, VectorGen did not prove to be as useful as hoped for the purposes of testing hardware, but is a powerful tool that could be even more beneficial if changes are made to make it more viable for hardware test.

Unfortunately, the VHDL code for this particular design was significantly complex, therefore a small portion of the FPGA VHDL, the Asynchronous Serialization Module (ASM), was chosen for the specification. Within the ASM, we decided to begin with the TX to RX loop-back (See Figure 2.) Completing the loop-back would incorporate most of the features for an ASM port. Originally, it was believed that some Rosetta code had been written that incorporated parameter-passing capabilities between facets. Using this information, Rosetta code was written emulating the SCM VHDL code, separating the code into multiple facets for inclusion into an encompassing SCM Domain. The SCM Domain would allow for facet interaction between code written for the VHDL, temperature and power consumption. When the code emulating some of the VHDL was run through VectorGen™, VectorGen™ operated nominally, but no data appeared in the output file, where the data should have appeared, blank space appeared. Upon further examination with the writer of the earlier Rosetta code, it was determined that the Rosetta code and VectorGen™ wasn't able to pass parameters. The writer of the code was taking the output from one facet and hard coding them as inputs into the next facet, instead of having the Rosetta facets pass parameters independently.

Once VectorGen™ had been used to generate the test vectors in the WAVES format; these vectors were provided to TACMS to test an actual SCM. Some problems arose as arrangements were being made to actually test the SCM using the WAVES test vectors. First, the inputs and outputs of the SCM's ASM are internal signals and are not actually inputs and outputs of the FPGA, so that particular module could not be tested with the current SCM configuration. Also, the method of specifying some of the VHDL inputs as constants, in order to simplify the VectorGen™ output, caused problems, since the actual hardware changes these inputs in normal operation. To resolve these issues, a new version of SCM FPGA firmware was written. First, the firmware routes the outputs of the ASM out to spare interfaces on the SCM so that they can be monitored externally. (The ASM inputs can be controlled indirectly from an external HP Probe.) Also, the ASM itself was modified to change those inputs which became constants in the Rosetta specification to actual constants in the VHDL. This makes the VHDL code match the Rosetta specification as closely as possible.

Finally, discussions with test equipment engineers revealed that LMMFC-D has no equipment that accepts WAVES test vectors for automated circuit tests. Instead, in order to perform an automated test on the SCM, a total reconstruction of the test software would have to be done to accommodate the WAVES input. Time and cost constraints pointed us in another direction. It was decided that an automated test could be simulated by manually providing inputs to the SCM (in a “stack-level” configuration) from the WAVES test vectors and checking the outputs on an oscilloscope to see how they compare to the predicted WAVES test vector outputs.

Technically, Rosetta and VectorGen™ performed quite well. As mentioned above, no computation errors were found during testing. This indicates that VectorGen™ has been debugged enough to handle moderately robust systems, even though it is still in a developmental phase, and should be dependable for future programs.

The use of VectorGen™ and Rosetta could also be applied to remove some of the steps in the normal requirements verification process. The automatic generation of test vectors could eliminate the need to create new tests for each requirement in the test software and could remove the need for a “stack-level” test. However, when it comes to actually testing the hardware against WAVES output, problems arise. The main benefit of the WAVES test vector format is its simplicity, which allows the format to conceivably be used to test almost any system, including thermal and mechanical systems. This simplicity also allows a significant amount of information to be gleaned from the WAVES output in a short amount of time, since the WAVES output is simply a printout of the possible inputs and the expected outputs for each input. However, the simplicity of WAVES also restricts the format. The initial goal of this project was to perform an automated hardware test with the WAVES output from VectorGen™. However, none of the engineers contacted for this project (both at LMMFC-D and at EDAptive) have ever used WAVES to test hardware or knew of any board-level test equipment that utilized WAVES test vectors. Accordingly, to actually create a test setup that utilizes the WAVES format, a totally new version of test software would have to be generated. So, the benefits of removing steps from the original requirements verification process are dimmed somewhat by the addition of two significant steps: writing a Rosetta specification to the requirements of the design and generating test software capable of accepting and testing to the WAVES format. If VectorGen could provide standard output that could be directly used by automated test equipment, it would become a much more viable tool for testing and verifying hardware.

Another benefit of VectorGen™ is its thoroughness, but again, this benefit can also be a downfall. For each Rosetta specification that is provided to VectorGen™, it provides a unique set of outputs for every possible input combination. This could allow for problems to be discovered for input combinations that would not be tested under the normal process, since none of the hardware test techniques used by TACMS are this thorough. However, the problem with such thoroughness is the size of the output, which increases exponentially with the number of inputs into a system. For example, if a digital system has a certain number of inputs n, then the number of possible input combinations for this system would be 2^n (for analog systems, this number could be even greater). So, for a design such as the entire SCM FPGA, which has approximately 150 inputs, the number of lines of WAVES output would be about 1.42×10^{45}. Because the output becomes so large with a higher number of inputs, VectorGen™ can only be used to generate test vectors for very small systems with limited numbers of inputs. To make VectorGen™ a useful tool for this type of design, additional requirements must be added to the Rosetta specification to limit the amount of output, either by deciding which inputs are relevant or by randomly selecting a small number of inputs to be tested.

Because of the problems listed above, the current feeling of the TACMS Program Engineers is that VectorGen™ is not yet cost-effective enough in its current configuration. However, assuming these issues are resolved, it may be still too early in its application to determine whether the replacement of the current requirements verification and hardware test processes with one incorporating VectorGen™ would be beneficial to a program.

A number of questions remain to be answered. First, would writing a Rosetta specification based on a set of requirements save time and money over creating tests in test software for each requirement? If the requirements change in the future, would the required changes in the Rosetta specification take more time than the changes required by the current process (changing the tests in the test software)? Can VectorGen™ and Rosetta create a board-level test that thoroughly checks every aspect of a circuit board, so that the "stack-level" test of the current process is no longer needed for requirements verification?

8.4.8 Cost/Benefit Analysis

The SLTA Pilot Project was a valuable experience which could result in significant savings for future designs. The following cost/benefits analysis though, does not include initial development test savings or early fault isolation due to affordable testing at a lower level that avoids higher cost events (misdiagnosis of design issues, retest and additional redesigns). It also does not include potential savings from risk reduction, internal (interface) visibility, or faster change management.

A Missiles and Fire Control - Dallas baseline design approach is estimated to cost:

Create a typical circuit card assembly (design & test) = $300K

The cost of a typical number of design changes and iterations must also be estimated and costed.

Cost of 5 design iterations/yr/program = $1.5M

(Using a programs avg. of ~100 cards and 5% of those need redesign each year)

Using this same estimation method, System Level Design Approach Costs can be estimated to be as follows:

Software License Cost (2002 Pricelist) = $25K
(One-year term w/40 hours telephone & email support)

Rosetta Training Cost (not including travel) = $6K
(Materials, 1-day tutorial/workshop, test-case, one day of follow-up)

VHDL Code & Test Vectors creation labor (per board) = $150K
(1 design engineer X 1000 hours X $100/hour) + (50K test and evaluation)

Total SLDL Board Development Cost (per board)	=	$231K
Cost of 5 design iterations/yr/program	=	$536K

(1st design = $231,000, 2nd thru 5th = $304,920 (66% savings per iteration)

Based on this analysis, the savings at 5 design iterations/yr/program would be:

Savings (per program)	=	**$964K**
Enterprise Savings (averaging 10 programs per year/per site)	=	$**9.641M**

8.4.9 Conclusions

The SLTA Pilot Project was a good learning experience as a first time run through the still developing Rosetta and VectorGen™ process. But, as with any learning cycle, there are issues that could have been resolved differently, which resulted in several lessons learned.

One item which might have been done differently is the inclusion of the current ATACMS hardware design engineers in the initial decision-making process. For example, one of the problems noted by the current design engineers was that the SCM CCA and VHDL code emulated in the pilot project was one of the more complicated pieces of hardware. Also, the particular VHDL code that was used to create the Rosetta specification had been made obsolete by more recent versions of the code. So, if the current ATACMS engineers had been included, they might have provided a less complicated piece of hardware and assistance in locating the most up-to-date version of their VHDL code.

Another issue was that of creating code at a higher, systems level. Most code written in any language controls the minute details of the system. So, creating code to generalize the complete system was a new experience for the Rosetta programmer, and most of the code was written at such a concentrated level that it was determined to be too detailed for planned operation of the VectorGen™ software, which resulted in much time lost in correcting unusable code and reproducing “higher” level code.

Without information on how easily Rosetta and VectorGen can be used to test an entire system from the system’s requirements, it’s difficult to accurately quantify the cost differences from the current requirements verification and hardware test processes. Since our project focused on a small portion of the SCM FPGA, and since the specification was written from the actual VHDL code rather than the design requirements, time and effort for this project cannot be easily converted into a good estimate of the time and effort that would be required for testing the entire SCM. Also, gathering cost information for the original TACMS requirements verification process will require substantially more time and effort due to the difficulty in determining man-hours and the cost of equipment used, which has not been recorded in a form easily converted for our purposes.

In examining the results of this test, it is difficult to determine the value of Rosetta and VectorGen™ to future programs because of the issues mentioned above. With the project being a pilot, it should be expected that unforeseen issues could cause problems with the outcome. If a future evaluation of VectorGen™ is performed, it might be wise to change a few things. First, since TACMS is already in production, requirements verification and hardware test methods have already been established, so incorporating VectorGen would involve some redundancies in developing the new process. If a program was selected in its infancy, a Rosetta specification could be written from the design requirements and shape production hardware verification. Also, if a simpler design were selected, the written specification could describe all of the requirements for the entire system being tested, rather than a small portion of the system. In this way, the project could more easily determine the time and costs associated with the new process, since it could mimic what a typical program would experience.

Overall, this project has proved that VectorGen™ and Rosetta are powerful tools. However, more work must be done before it can be used effectively as a tool for requirements verification and hardware test. Further experimentation and analysis is also needed for an accurate comparison of the costs of using VectorGen™ versus the current processes being used.

8.5 F/A-22 / i2 LCM Pilot

Lockheed Martin Missiles and Fire Control - Dallas conducted the F/A-22 Automated Obsolescence Assessment (AOA) Pilot to explore the relative utility and validity of i2 Technology's Life Cycle Management (LCM) obsolescence data. During the AOA pilot, LMMFC-D personnel repeatedly queried their existing Component Supplier Management (CSM) system to analyze representative electronic component bills of material from F/A-22 subsystems. The study team then compared the CSM/LCM data on the representative components to obsolescence data from several of other data sources commonly in use by the F/A-22 and other Lockheed Martin programs. For example, the obsolescence database used historically by the F/A-22 was TacTech's TACTRAC database (acquired by i2 via their acquisition of Aspect Development after Aspect acquired TacTech). Other M&FC-D programs depended on Arrow Ubiquidata, TacTech AIM/MAX and/or Total Parts Plus. These were among the other data sources the study team compared.

To varying degrees, the study team also explored the data of several emerging obsolescence data sources including (in alphanumeric order) 4D Online, Avnet Promiere, IHS/Precience, netCOMPONENTS, Part Miner, PCNalert, QTEC's Q-Star™ and SiliconExpert.

While this list of tools is large, a few commonly used data sources were not included. For example, several Air Force programs use the Manufacturing Technology Incorporated (MTI) supported Avionics Component Obsolescence Management (AVCOM) database. While it was not available to us during this pilot, the obsolescence data in AVCOM is essentially redundant with Total Parts Plus, a MTI developed data service that the AOA study team did assess.

In a similar overlap, the study team found that 4D Online and Avnet Promiere tools incorporated online implementations of the i2 LCM data. While the 4DOnline and Promiere user interfaces were different from the M&FC-Dallas i2 CSM/LCM implementation, these tools have essentially the same underlying quantity and validity of the LCM data. Thus conclusions about LCM data can be applied to 4D and Promiere, and those from Total Parts Plus can be applied to AVCOM.

The study team did a preliminary assessment of the utility and validity of several sources of obsolescence data during the AOA pilot. All the available tools were found to have very good but not identical performance.

Variances in the tools could make one tool better than another for a particular situation and set of constraints. For example, all the tools the study team evaluated had adequate performance for new development programs but some, like those from Total Parts Plus, i2/TACTech and IHS/Promiere, had better historical component data that would be more valuable for older production and sustainment phase programs. Some tools like i2's and SiliconExpert's had an extensive data base of component parametric data making them stronger candidates for engineering part-selection tasks or for obsolescence mitigation by selecting alternative parts. PartMiner, Promiere and Ubiquidata had information on current market volume conditions, distributor inventory and pricing data that would make them powerful tools for procurement and materials support. Other tools had the advantage of being in use by certain DoD customers. For example, the Army's obsolescence working group in Huntsville uses Total Parts Plus to monitor obsolescence on its programs like MLRS, TACMS, THADD and PAC-3. This makes Total Parts Plus the logical choice for Army programs while AVCOM is used on many Air Force programs. Although a newcomer to the field, QTEC's Q-Star™ system is now available to the entire DoD obsolescence community and is designed to facilitate collaboration across programs and services. Q-Star™ thus may eventually become the baseline tool of choice for most individual programs and enterprise obsolescence data needs.

Another deciding consideration is technical data security and integration. Some tools offer higher levels of security and/or integration with company back-office processes. For example IHS/Prescience and i2/SRM are designed for deployment on private servers (behind company firewalls) that integrate with Enterprise Resource Planning (ERP) and Product Data Management (PDM) servers at the enterprise level. This architecture allows increased security compared to systems that operate from public servers over the Internet.

Thus the study team found that the selection of a tool is a complex process of matching performance, cost, and features for each particular requirement. In summary, no one tool can be considered the "best" for all needs and a tool mix seems to best meet complex needs for coverage, security, integration, collaboration, usability, and accuracy. The AOA study found that reliance on only one source of data could actually result in increases in the cost of managing obsolescence while multiple data sources significantly improves the probability of identifying issues early enough to use solutions (like bridge buys) that are significantly less expensive than others (like aftermarket or emulation).

8.5.1 Background

In the mid 90s, Lockheed Martin Missiles and Fire Control – Dallas (previously Loral Vought Systems) began trial evaluation of Aspect Development's Component Information System (CIS). The CIS system was tested on the Line of Sight Anti-Tank (LOSAT) program to provide an integrated source of component data to enterprise functions like Engineering, Quality, Manufacturing, and Procurement. In 1998 after successful CIS trials on the LOSAT hypervelocity missile development program, Dallas procured an improved version of CIS, called Component Supplier Management (CSM) system, at a cost of about $2.5M. During CSM implementation and deployment, Aspect Development integrated the CSM system with Dallas' Computer Aided Engineering (CAE) tools (like Cadence for electronic design and ProE for mechanical design), their Enterprise Resource Planning (ERP) system (R/3 from SAP) and Product Data Management (PDM) system (previously CADIM from Eigner, now PLM from Agile).

This deployment provided an integrated environment with consistent component parametric performance data, part numbers, quality data, inventory data, pricing data and order status information. Dallas engineers had access to the data sheets for millions of components and could rapidly conduct parametric searches for electronic components to meet specific requirements. Engineers could then transfer selected items to Cadence circuit simulations and Pro-E manufacturing drawings. Component Engineers automatically reviewed the choices to assure approved sources are used and that the remaining production life of the part is adequate for the application. Released part lists were transferred electronically (without human transcription errors) to Materiel Department buyers for purchase and to Quality Assurance for receiving inspections. While in production, Manufacturing Department personnel could monitor availability and producibility of the design while Logistics and Support personnel could assess long-term design viability for impacts on maintainability and availability of the equipment. This unprecedented level of tool integration proved a very valuable and cost effective infrastructure even thought the implementation was complex and costly.

As part of this data integration, the CSM integration team selected TacTech AIM/MAX (the obsolescence tool used by the Multiple Launched Rocket System (MLRS) program, and several other programs in Dallas to provide component obsolescence information to the CSM enterprise tool. Aspect Development considered the development of a lifecycle data system similar to TacTech's. However, due to the risks and time required to gain customer confidence and acceptance, the CSM integration team recommended Aspect incorporate TacTech data instead of developing their own data.

At about this time, the Air Force Research Laboratory and others in the DoD community recognized the need for improved lifecycle predictions that are integrated with the engineering, manufacturing and support processes. Instead of identifying part discontinuances as they occur, a means of predicting the availability of component technology was needed to allow efficient planning and management of technology refresh and system upgrades. To develop improved predictions, the AFRL Part Obsolescence Management Tool (POMT) effort selected the Aspect Development - Raytheon team to design a commercial predictive lifecycle management system for electronic components. Aspect developed their Life Cycle Management (LCM) technologies with both predictive data and new software that employed these predictions to help visualize and manage configuration item obsolescence risk.

As Aspect's technology matured, it evolved rapidly through several releases and name changes. Aspect based their eDesign obsolescence predictions on a proprietary process that combines relevant market, technology, and product lifecycle data. Aspect also decided to acquire and adapt TacTech's AIM/MAX and TACTRAC technologies into their LCM and eDesign tools. Aspect released and began marketing their new eDesign tool and the related LCM data to both existing CSM customers (Lockheed Martin, Boeing, Northrop-Grumman, Raytheon, etc.) and to new customers. Soon the merger of Aspect Development and i2 Technologies was realized and the product name was changed from eDesign 2.0 to Supplier Resource Manager (SRM) 5.2 as a part of i2's software tool suite. Thus the technology known as LCM went through several releases and name changes during the course of the POMTT program.

In early February 2000, a coordination meeting and demonstration was held at Aspect Development in Mountain View, CA. Some of the current and planned capabilities of the eDesign system to identify and predict obsolete electronic parts were demonstrated for attendees from Orlando, Marietta, Binghamton, and Dallas. An action item to define and compare the capabilities in the current implementation of Aspect tools in Dallas with that being developed under the AFRL BAA was assigned to Aspect. The overall toolset developed for POMTT pilots needed to cover both reactive tasks, e.g., replacement of obsolete parts on current equipment, and proactive tasks, e.g., Designing For Obsolescence Resilience (DFOR) on new systems. Aspect had already participated in developing numerous business cases and stated that they had 10 to 15 that could be used for reference.

Although it was not clear which version of the Lifecycle Management (LCM) module was being demonstrated, it was clear that LCM was being designed to facilitate design optimization by allowing both component selection and supplier selection trades versus life-cycle costs that are a function of predicted obsolescence of components. The LCM was being built with extensible code so that it can be customized, and it has flexible Graphical User Interfaces (GUI's) that can be tailored per application and/or per person. The user could also customize the "reference content" including the meaning of obsolescence scores so that a sole-source part can be identified with the color red to some users, and yellow or green to others. Aspect consulted extensively with CALCE and numerous component experts on the meaning of their standard life cycle scores.

Aspect planned to use numerous sources to acquire life cycle data. These included Dunn & Bradstreet for DUNS Codes, EAP information (minority representation at suppliers), and supplier financial information such as bankruptcy claims, etc. Aspect also had proprietary web agents that continuously checked numerous web sites for part failure alerts, change notices, and other critical data to update the database. SemiCo

Research also provided input to LCM by forecasting unit sales and has provided one-year forecasts that historically were within 3% of actual sales. Overall, SemiCo's data accuracy averaged 5% since starting in 1994.

Aspect pioneered using a "Standard Classification System" (SCS) for classifying electronic parts. SCS recognizes the Electronics Industry Alliance (EIA) standards where applicable. Their early databases contain about 6.4 million commercial parts and 68,000 military parts from 921 different manufacturers. They had about 350 different part classifications with on approximately 30 different data parameters per part class. Included in the database, was about a million parts with LCM content from over 500 different manufacturers. LCM was designed to provide remaining life predictions for LCM content including anticipated production alert predictions, not just end-of-production predictions (years to procure as well as years to obsolete). Form, fit and function data was included to support alternative part assessments and replacement decisions.

Under Aspect's PO effort at Raytheon, eDesign replaced eXplore 4.x and provided the new Life Cycle Management (LCM) capability. Aspect demonstrated eDesign/LCM's capability for Automated Decision Making for parts and module designs, Smart Searches, Life Cycle Forecasting, and access to contact information on site-specific programs. The LCM module provided an overall score for a circuit card design, pointed out that one part was discontinued, and generated an Excel 3D graph of the overall design maturity and obsolescence issues. The LCM module also found an alternate for the obsolete part and reran the design evaluation, resulting in a 57% score improvement. Finally, each design iteration was archived for reference.

Aspect was therefore asked to prepare a detailed statement of work to support to the initial baseline development and LCM tool implementation during the POMTT effort at Lockheed Martin Missiles and Fire Control - Dallas. This was because it was unclear how or when Aspect intended to provide the LCM module or support its evaluation; especially as functional requirements for the module were still being defined.

Several issues were identified during a follow-up meeting. Since the requirements for the next version of LCM were still being finalized, the development of the LCM module was significantly behind schedule. Secondly, the current and subsequent versions of the LCM module appear to be defined to work with a version of Aspect (eXplore 5.x) that is newer than the Version 4.3 that is implemented in Dallas' CSM environment. Therefore, assessment of the LCM module by the pilots could prove to be limited in scope because the LCM module would not work in Dallas' engineering tool environment. Unless Aspect supported the evaluation of newer "beta" versions of the LCM module, Dallas would not be able to evaluate LCM unless it was compatible with their current CSM release.

Missiles and Fire Control - Dallas initiated contacts with the other Lockheed Martin campuses for coordination of the pilot programs. Lockheed Martin Aeronautics Systems - Fort Worth (LMAS) (formerly Tactical Aircraft Systems) participated in a meeting of an LMAS study group to assess Total Ownership Cost (TOC) modeling of aircraft systems (since obsolescence issues have a major impact on TOC). Potential pilot programs included LMAS programs like the F-16, F-22 and JSF and coordination continued with Dallas' in-house programs like LOSAT, LOCASS, TACMS, PAC-3, and MLRS. Schedules of each of these programs were collected to assess their fit with Dallas' POMTT pilot plans.

An updated requirements specification for the i2 Life Cycle Management (LCM) module was received in November 2000 and Lockheed Martin comments were compiled by early December. A summary of that specification and Lockheed Martin comments (in italics) is provided as follows:

- *What is the baseline?*
- *Some statements are not clear*
- *Not sure what* "The user can enhance these algorithms to support the profiling of their product design methodology" *means. How is it done - through profiling?*
- *What does* "Existing Obsolescence Information" *mean? Is it coming from a component supplier? How often?*
- *What does* "Alerts are received dynamically" *mean?*
- *Change control is normally a function of PDM and should not be in LCM. Perhaps you should focus on providing data through an interface to a PDM system for automating the approval process.*
- *Dallas' LCM content MUST be designed to support the same currency required for other mission critical operations like inventory management. Most of the performance data will not change from day to day but lifecycle content often does and delay in dissemination is unacceptable. Dallas' current systems are based on the telephone and email and thus often respond in near real time to an obsolescence status change. We can't afford to go backward.*
- *Statements need more details such as: What database version, operating system version, eXplore version will be required? What are the compatibility and interface constraints with past, current and future i2 solutions and modules? (This would be a good place to add or refer to an interface document that describes the BOM import interface and what "data standards" and formats will be supported.) Industry standardization with DoD and other obsolescence tools will be important for broad acceptance.*
- *Define the required analysis and output form. Numeric with uncertainty or confidence both at time now and at future times is needed.*

- *The where-used analysis update function may also be connected elsewhere in the DesignManager suite or may need to interface to the PDM change process; i.e., not all in LCM.*
- *Collaboration is normally done by phone, email, and meetings. An automated capability to inform other programs about solution choices, schedules, quantities, and status is needed.*

By the 2nd Quarter of 2001, based on i2's presentations at the EPOI workshop and LCM steering team meetings, M&FC-D anticipated i2 would complete tool development and demonstration by mid-year. However, there was concern that, if LCM's release was further delayed it would not allow enough time for the tool to be implemented in a fully deployed form. Therefore, Dallas developed contingency plans to assess LCM without a full implementation. Dallas provided a summary chart on its understanding of i2's development progress and potential pilot evaluation at the Spring EPOI Workshop (Figure 8.59).

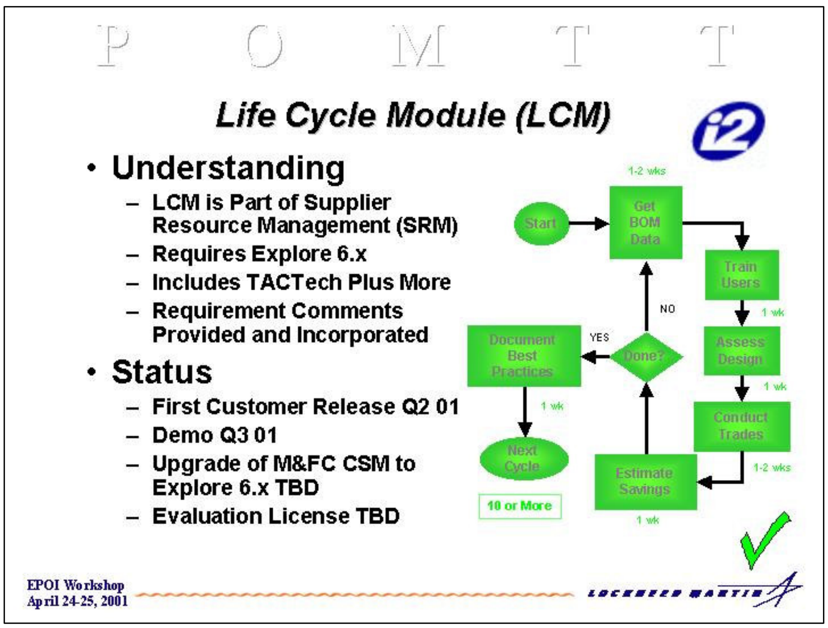


Figure 8.59 – LCM Pilot Potential

By the 3rd quarter of 2001 the LCM tool from Aspect Development (now i2 Technologies) was still not available. The Life Cycle Manager module was a primary candidate for Dallas and Orlando pilot projects. The Component Supplier Management (CSM) system was also installed and in use in Dallas. Therefore, proposals were requested, received, and evaluated to migrate Dallas' CSM implementation from its current eXplore 5.0 based configuration to Version 6.0 to support evaluation of the new LCM module after it is released. A development and evaluation server was set up for implementation of the module.

To support the potential pilot, i2 requested Dallas to compile a list of parts for assessment. The submitted list contained over 2500 parts from a number of Lockheed Martin sites, including Marietta, Sunnyvale, Dallas, Fort Worth, and Orlando. Although the list was provided to i2 the demo was delayed by the September 11, 2001 terrorist attacks.

A concern about the lack of a commitment by i2 (illustrated in their reluctance to provide an LCM evaluation license or detailed plans for pilot implementation) continued to grow, so Dallas explored further contingency plans to assess LCM through one of their major suppliers who was implementing the i2 solution with the LCM module. However, by the first quarter of 2002 the Dallas POMTT Pilot had organized a demonstration of the i2 Life Cycle Management (LCM) Module. Although this was not an on-sight evaluation of LCM, Dallas' tested a consolidated list of parts from various aircraft and missile programs with their existing CSM system to see how much part data was available in the i2 database. They found that generic part numbers produced multiple sources, as expected.

In another instance, Bob Jeffers, POMTT program Manager at Lockheed Martin Missiles and Fire Control – Orlando, requested i2 make the tool available. Greg Metzger, i2 Lockheed Martin Account Manager indicated that he had repeatedly asked i2 management to support such an evaluation, but unless Lockheed Martin commits to implement an upgraded system, an evaluation license was not acceptable to i2.

Therefore, in the second quarter of 2002 Dallas began assessing requirements for an i2 TacTech AIM/MAX replacement. Plans were also explored towards the feasibility of a pilot evaluation of the i2 LCM Content Data which was now available in the new i2 Electronic Database (ED). Dallas received a quote from i2 and agreed to procure the LCM Content Data for use in Dallas' CSM system. Although it did not include the SRM software suite, the Content Data did include all of the Life Cycle Manager obsolescence predictions used by the SRM software. Dallas also received quotes to extend their current licenses to upgrade to i2's SRM Product Sourcing software (with LCM modules) and another to make both the LCM data and software available across the entire Lockheed Martin Corporation. The first offer of LCM content and SRM technology was explored as a cost-effective alternative to Lockheed Martin's practice of setting up multiple independent installations of TacTech's AIM/MAX and TACTRAC licenses, and maintaining standalone data on each individual program with little collaborative effort.

8.5.2 <u>Initial Pilot Recommendation</u>

Since no commitment for an evaluation license had been received by this time, Dallas decided to recommend an i2 pilot that would support implementation and refinement of custom CSM interfaces using the i2 LCM content data. At the 2002 MCES Symposium, Dave Darling, and Doug Fuller met with i2 (Jay Graver and Greg Metzger) to discuss options for an in-depth evaluation of the LCM data and functions in SRM. It was emphasized to i2 that Dallas' program personnel on MLRS, TACMS, PAC 3, etc. were very nervous about losing TacTech's AIM/MAX. Also discussed was a potential pilot approach to define and test the use-model of LCM with CSM to make sure that current users of AIM/MAX can easily use LCM which would replace it. Greg stated that, since Missiles and Fire Control had extended their content license to include LCM data, i2 would possibly be willing to support an evaluation of the SRM solution. Therefore, at the Planet Conference, a verbal agreement was established to work together to support a pilot, or pilots at Lockheed Martin.

In the 3rd Quarter 2002 Dallas submitted a pilot plan to use the LCM content data in an evaluation of the obsolescence management effort of several Lockheed Martin programs. Initial efforts were to focus on applying LCM to the Multiple Launch Rocket System (MLRS), Army Tactical Missile System (TACMS), Low Cost Autonomous Attack Submunition (LOCAAS), and Patriot Advanced Capability (PAC 3) programs in Dallas. The pilot would also include programs from other Lockheed Martin sites, like AEGIS, F-22 and F-16 as available. This would also result in synergy as the Orlando POMTT personnel explore the functionality of the SRM software and Dallas focuses on the LCM's data and functional capabilities as compared to other alternatives and LMC baseline tools.

In August however, AFRL rejected this proposed plan so Dallas started work to revise their plan to focus on assessment of obsolescence for the F/A-22 Program using the i2 LCM content tool.

In the meantime, concerns started to build about i2's financial stability during the stock market downturn. At i2's Upgrade Workshop at i2 Technology headquarters in Dallas on 13 August, i2 presented their financial status to mitigate concern about their business future. Pallab Chatterjee, President, Solution Operations, indicated that i2 had sales of $120M in Q2 of 2002 and that i2 has cash of $615M with no short-term debt. This is about the same performance that i2 achieved in 1999 before the stock market bubble burst. Pallab explained however, that i2 was reorganizing their sales approach that focuses on current customer needs. In this new organization, the primary i2 contact would be assigned to an account manager from consulting, rather than from sales. At the same meeting, Dave Lassiter, Vice President of SRM Global Sales Support stated that a general approach to an upgrade now required a 6 to 8 week effort in India in order to minimize cost for data migration. This work was previously performed in the U.S. but was moved off shore to reduce costs. This raised issues concerning data security since the U.S. Government restricts technical data to domestic distribution.

While this capability is of interest to some i2 customers, most of the Aerospace and Defense customers are either Aspect Development or TacTech legacy product users who are not implementing the purchasing functions of SRM. They are only planning to use the part management and obsolescence assessment functions of the SRM product.

Electronic components data was extracted for analysis using Dallas' new CSM Report based on LCM data. Test cases were run and worked with MLRS personnel to determine how LCM assessments compared with obsolescence assessments by their supplier (Radstone) and their customer (AMCOM). CSM reported six obsolete parts that neither Radstone nor AMCOM identified. It also identified sources for five parts that had been classified as obsolete by AMCOM. This effort clarified the need for further automatic assessments of unrecognized and generic part numbers.

At the same time, Dallas continued to work with Lockheed Martin Aeronautics Corporation (LMAC) programs in Fort Worth and Marietta. George Sacarelos, Lockheed Martin Aeronautics in Marietta, initiated a study to assess LMAC obsolescence-analysis tools. He also requested support from Dallas in the assessment of these tools and the development of a coordinated corporate approach to selection and implementation. Discussions were held about F/A-22 program's participation in an i2 Content Data Pilot evaluation.

Exploration of the automation of Dallas' AOA pilot process (collecting data from various tools) continued and found that partial automation of the data collection and comparison was possible, but the goal of full automation may not be feasible within the resource constraints of the AOA pilot. So in September the program developed and tested a Visual Basic program to automatically generate an LCM report and assign it a name that is date dependent. This will facilitate repetitive reports for comparison over time. A new spreadsheet was also developed that compares the results of two LCM reports and automatically finds the changes in these reports. In October, this tool was used to compare F/A-22 LCM reports from June and October. This demonstrated the unique ability to screen reports and look for significant changes in LTB date and part status.

Prior to the start of the F/A-22 AOA Pilot, LMMFC-D implemented parts of i2's tools but did not upgrade to the full SRM tool. As mentioned earlier, Lockheed Martin Missiles and Fire Control – Dallas had utilized i2's CSM tool but obtained obsolescence status data on part numbers in CSM from TacTech. In Orlando, Lockheed Martin also used TacTech AIM/MAX to provide data to their obsolescence management process. When Orlando and Dallas were merged in to the Lockheed Martin Missiles and Fire Control business unit, CSM became available in both Dallas and Orlando. Thus it then became more cost effective for Lockheed Martin Missiles and Fire Control to begin utilizing a license for the newly available and much larger database, LCM, rather than two licenses for TacTech's AIM/MAX. A full upgrade from CSM to eDesign was considered but was not implemented during the AOA Pilot because of complexity and cost. The complex task of implementing and rolling out the CSM system was still underway and the CSM integration team was not prepared to quickly upgrade to a newer technology before the new system was fully deployed, debugged and its users training completed. Additionally, the proposed cost for upgrading to eDesign was over $1M. Instead, for a much lower cost, LMMFC-D licensed LCM data for use in the existing CSM system.

Thus during the development of SRM/LCM, Lockheed Martin was an active user of the related technologies and helped to guide its continued development, requirements definition, integration, and user interface refinement. The F/A-22 AOA Pilot provided Lockheed Martin with expanded support for tool implementation and evaluation and provided the Air Force with objective feedback on the costs and benefits of these emerging capabilities.

8.5.3 Pilot Approach

As described in the previous section, prior to the approval of the AOA pilot in late 2002, Lockheed Martin Missiles and Fire Control - Dallas participated in the early phases of the POMTT program to work with i2 Technologies to help them define and implement the LCM extensions to the CSM tool. During this pre-pilot phase (between late 1999 and late 2002), Dallas' POMTT program participated in the AOA-related AFRL workshops and steering committee activities to:

Identify the parts obsolescence management tools that are available to be used in Dallas' pilot program. This task was initiated and several potential tools and their vendors were identified with interface discussions.

Assess how EPOI tools integrate with Dallas' design and production processes and ongoing production program schedules - Ongoing production program personnel and leaders for Dallas' enterprise design and production processes improvements were contacted. Preliminary discussions and review of these activities began and continued throughout the pilot.

Document the deficiencies and needs that should be addressed when modifying the tools for use in the pilot program.

Establish the metrics and criteria for choosing programs and tools to use in determining the baseline process and costs of obsolescence management.

8.5.3.1 AOA Pilot Approval:

Since Dallas did not have the full SRM solution, they developed a custom report function that used the new LCM data. Since an upgrade to the new SRM Product Sourcing technology was inconsistent with the company's 2003 capital funding limits, Dallas' decided to focus a pilot on the evaluation of the i2 Electronics Database (ED), and specifically its LCM content using Dallas' custom data report interface. The primary objectives of the pilot were to:

Use i2's Life Cycle Management (LCM) Content to automatically monitor obsolescence status for the F/A-22 and other Lockheed Martin programs.

Compare LCM to alternative database tools like TACTRAC, Parts Plus, Arrow-Avnet, etc.

Assess relative cost effectiveness like data inclusiveness, data accuracy, data latency, ease of use, integration feasibility, tool flexibility, implementation costs, etc.

The AOA pilot would improve Lockheed Martin's interface workflow and compare the breadth, depth and latency of LCM content with other data sources like IHS or Total Parts Plus. Therefore, a telecon was held with AFRL to discuss and revise the Automated Obsolescence Assessment (AOA) Pilot Plan. Jim Houston, George Sacarelos, Mike Mullins and Doug Mashburn from the Aeronautics Sector participated. Bob Jeffers and Dave Darling from Orlando also participated. Bill Russell and Brandon Lovett at AFRL reiterated their need for close coordination with a major AF program.

After discussing the general support the pilot gives to several DoD programs, it was decided to focus the pilot on the F/A-22 and include other programs as available.

F/A-22 is in a mature design state with ongoing obsolescence issues. In addition, avionics in the F/A-22 will be merging with those for the F-16 and JSF as these programs evolve. Thus, these other major Air Force programs will benefit from the AOA Pilot while the F/A-22 will provide a focus for tool evaluation and comparison. After the telecon, the pilot plan was revised and resubmitted to AFRL and, although approval was anticipated, additional questions emerged. AFRL requested additional clarification of the F/A-22 program's intent to participate in the pilot and use the pilot's findings. A recent F/A-22 program DMSMS working group invitation was forwarded to AFRL where George Sacarelos had requested Dallas' participation in the evaluation and assessment of obsolescence tool alternatives for the F/A-22 program. Then a more specific endorsement was drafted and sent to AFRL. Next, an endorsement from the F/A-22 program office was prepared and sent to AFRL with the appropriate SPO contact, Bruce Peet, at the Air Force F/A-22 SPO program office. Finally, AFRL requested additional coordinated cost/benefit analysis for the F/A-22 program which was provided and is identified in Figure 8.60.


F/A-22 Program Goals

	Current Methodology	LM/i2 LCM Approach	Benefit (Cost)
1.0 Military Component Coverage	70%	85%	15%
2.0 Commercial Component Coverage	8%	85%	77%
3.0 Passive Component Coverage	0%	80%	80%
4.0 Data Accuracy	60%	80%	20%
5.0 Supplemental Data (Manual Research) Cost	$300k	$100k	$200k
6.0 Annual Tool and Support Costs	$ 65k	$ 100k	($35k)
7.0 Costs of Obsolescence Resolution (Estimated)	100%	98%	2% $2M

Figure 8.60 – LCM Pilot Potential

As a result, in late November 2002, Dallas received approval for the F/A-22 Automated Obsolescence Assessment (AOA) Pilot plan. Dallas began to focus on conducting and completing the AOA Pilot plan and the F/A-22 program began preparing lists of components for use during the pilot.

A Dallas meeting with the IT department suggested that the IT department also participate in the AOA pilot to help determine what level of support would actually be required for off-site users. This could be used to base their recommendations for charge back fees on use of the tool outside of Missiles and Fire Control and IT agreed to support the AOA pilot.

The pilot established the following objectives:

1. Apply i2's Life Cycle Management (LCM) Content to automatically monitor the obsolescence status of F/A-22 and other systems.
2. Compare LCM to other alternative database tools (TACTRAC, Total Parts Plus, Arrow-Avnet, etc.)
3. Assess relative cost effectiveness for data inclusiveness, accuracy, latency, ease of use, integration feasibility, tool flexibility, implementation costs, etc.)
4. Recommend a corporate strategy

The revised schedule and tasks for this pilot are shown in Figure 8.61.

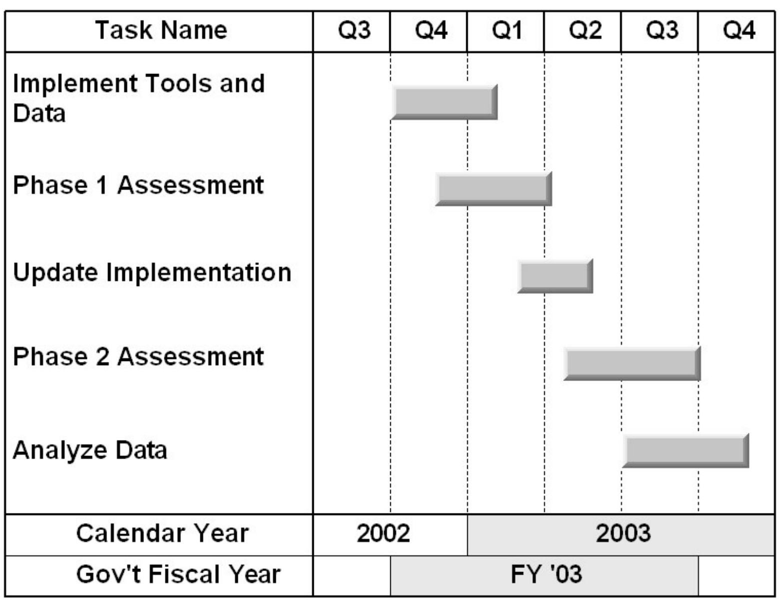
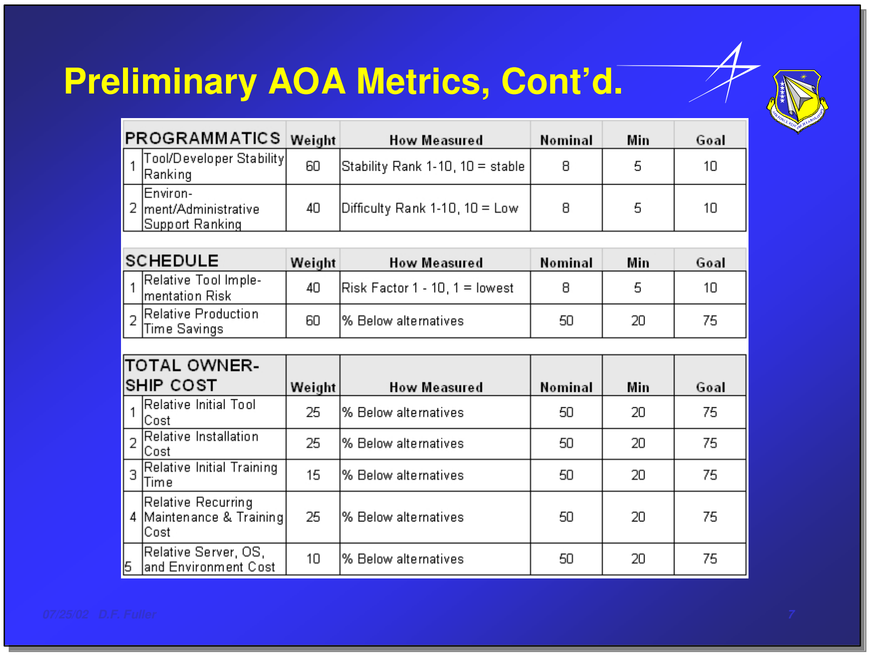


Figure 8.61 – LCM Pilot Schedule

The approach would apply LCM to leverage the current M&FC LCM integration, allow Dallas to review multiple commercial providers, leverage multiple interface investments already made at M&FC, and take advantage of Lockheed Martin's experience with i2. F/A-22 was selected since it was a high visibility program, the Air Force's newest production fighter, and was already experiencing obsolescence issues. Other programs data would also be included to help evaluate other programs in various phases of maturity (concept, design, production, deployment, sustainment, etc.), to help identify synergy across the corporation, and to explore various needs between components and subsystems.

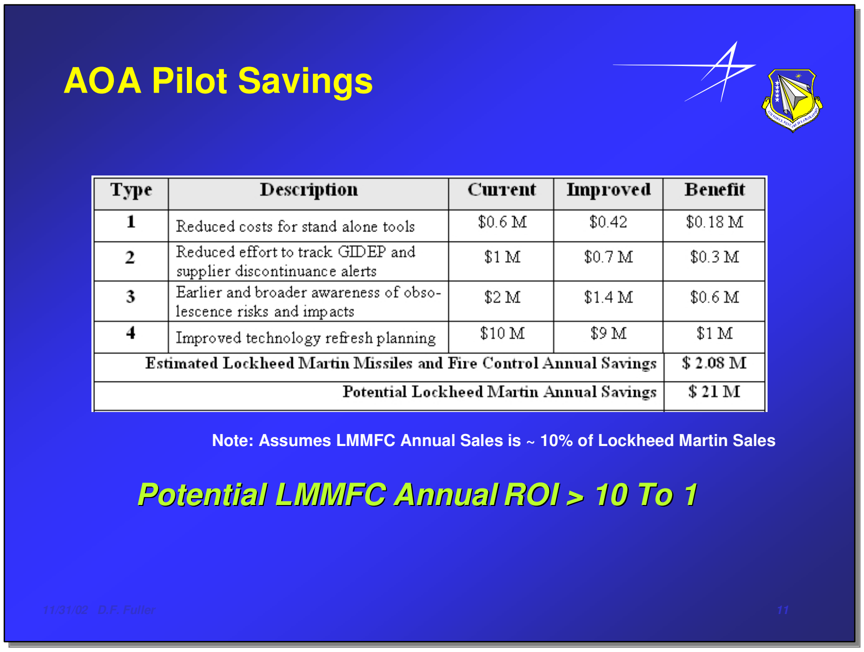
Preliminary metrics were established to quantify the costs and benefits of the i2 solution. The metrics, groupings, and preliminary weightings are provided in Figure 8.62.



PROGRAMMATICS		Weight	How Measured	Nominal	Min	Goal
1	Tool/Developer Stability Ranking	60	Stability Rank 1-10, 10 = stable	8	5	10
2	Environ-ment/Administrative Support Ranking	40	Difficulty Rank 1-10, 10 = Low	8	5	10
SCHEDULE		**Weight**	**How Measured**	**Nominal**	**Min**	**Goal**
1	Relative Tool Imple-mentation Risk	40	Risk Factor 1 - 10, 1 = lowest	8	5	10
2	Relative Production Time Savings	60	% Below alternatives	50	20	75
TOTAL OWNER-SHIP COST		**Weight**	**How Measured**	**Nominal**	**Min**	**Goal**
1	Relative Initial Tool Cost	25	% Below alternatives	50	20	75
2	Relative Installation Cost	25	% Below alternatives	50	20	75
3	Relative Initial Training Time	15	% Below alternatives	50	20	75
4	Relative Recurring Maintenance & Training Cost	25	% Below alternatives	50	20	75
5	Relative Server, OS, and Environment Cost	10	% Below alternatives	50	20	75

Figure 8.62 – AOA Pilot Metrics

The following Figure (8.63) illustrates the potential savings that were expected using the tools and revised processes associated with the pilot. These savings would potentially consist of labor savings from the use of more efficient tools and processes, as well as material cost savings due to better awareness, more consistent tracking, and the purchase of program material before it becomes obsolete.



Type	Description	Current	Improved	Benefit
1	Reduced costs for stand alone tools	$0.6 M	$0.42	$0.18 M
2	Reduced effort to track GIDEP and supplier discontinuance alerts	$1 M	$0.7 M	$0.3 M
3	Earlier and broader awareness of obsolescence risks and impacts	$2 M	$1.4 M	$0.6 M
4	Improved technology refresh planning	$10 M	$9 M	$1 M
	Estimated Lockheed Martin Missiles and Fire Control Annual Savings			$ 2.08 M
	Potential Lockheed Martin Annual Savings			$ 21 M

Figure 8.63 – AOA Pilot Potential Cost Savings

In summary, by the end of 2002, when the Air Force formally approved the F/A-22 AOA Pilot, Lockheed Martin had i2's CSM system with LCM data deployed in Dallas and was in the process of deploying this system in Orlando as well. Lockheed Martin also had several programs using other tools so the study readily compiled data from both other obsolescence tools and their own existing CSM/LCM system.

LMMFC-D therefore began the F/A-22 Automated Obsolescence Assessment (AOA) pilot with ready access to both LCM data and other relevant data systems. During the pilot, LMMFC-D collaborated closely with the F/A-22 program in Marietta, GA to make sure that the information LMMFC-D was obtaining would directly benefit one of the premier Air Force systems.

8.5.4 Data Collection

As indicated in the pilot schedule, data collection was divided into two phases. After receiving component data from the F/A-22 program, LMMFC-D began to assess obsolescence of F/A-22 parts using the CSM/LCM tool and several other tools. Results were compared and relative performance of the tools evaluated.

8.5.4.1 Phase 1 Data Collection

In preparation for the assessment, a database was prepared with parts from subsystems of the F/A-22. Marietta provided Part Lists (PLs) for four representative F/A-22 subsystems. These were complete PLs containing hundreds of parts including raw materials, mechanical parts and electronic components. After combining the lists and isolating the electronic part numbers, the AOA pilot team consolidated them into a list of about 590 unique electronic part numbers, some of which were used more than once or in more than one subsystem. The team further divided the list into 158 active parts (transistors, diodes, microcircuits, etc.) and 340 passives (such as resistors, capacitors, connectors and inductors). The initial list of parts was then processed using the LCM report function in CSM/LCM.

Some of the part numbers were not recognized by any of the lifecycle tools so part numbers were valid. This manual validation was completed for 94 F/A-22 part numbers that were "unrecognized" during the initial analysis.

The program continued to organize and compile input data from other sources to facilitate objective assessments of competing obsolescence tools. For example, part lists from F-16 subsystems were added to the PartMaster database. Those part numbers were validate by running an LCM report on the F-16 parts and sending the reports to Fort Worth (Jim Houston) for further review.

The pilot program also received a part list for representative avionics from Chris Vachtsevanos, the DMS lead for C-130J in Marietta. The C-130 parts were filtered to determine which of them were active, and which were passive. A preliminary assessment was performed on these parts and found that the LCM database identified most of the active parts, but few of the passives, and those few actives that were not were found to be custom parts or specialty items not normally included in such databases. Thus the overall performance of LCM was quite good. Based on this assessment the program started a process to compile active and passive electronic components in separate lists.

The AOA pilot collected data on both the list of validated part numbers and occasional components of special interest. For example, there was special interest in one discontinued part from the F/A-22 program. George Sacarelos used the CSM/LCM Report tool and TACTRAC to search for Form, Fit, & Functionally (FFF) alternatives for the LM137AH voltage regulator. TACTRAC found 48 alternatives while LCM found none. Assessments of this disparity revealed how to best use eXplore to find alternatives. It was found that the TACTRAC report function was designed to find manufacturer-recommended alternatives not FFF alternatives. George was shown how to use CSM eXplore to find FFF alternatives and found 28 FFF alternatives with CSM. Other tools like Ubiquidata, Part Miner, TPP and Silicon Expert were also searched for alternatives, with various results.

To follow up on this finding, a technical interchange was held with i2 Technologies and discussed Dallas' preliminary findings regarding the LCM data. George Sacarelos, John Jones and Doug Fuller met with Chris Etheridge, Todd Meadows and Anuj Gulati at i2's offices in Dallas, and Bonnie Crow, Bill Furlong and Keith Doubleday joined the meeting by telecon and the Internet. Specific examples of alternate part reports from TACTRAC were presented and a live demonstration of CSM searches for alternate parts was presented. In these examples, the links between part numbers and alternates (particularly commercial alternates) were more robust in TACTRAC. Action items were defined to assess what data relationships in TACTRAC should be included in the LCM data model. i2 indicated that they were aware of some of the issues related to the data model structures in military and commercial databases and that they were in the process of integrating these two elements. Other issues were new, so i2 assessed the appropriate mitigation considering that an update to their product is scheduled for late 2003.

These efforts focused the pilot on a significant deficiency in i2's implementation of CSM and LCM. Correcting this and implementing other tools became a major emphasis. For example in early May, the program met with Randy Washburn in Dallas' IT department to discuss some of the pilot's findings and determine if changes to CSM were feasible to improve searches for alternatives. A new reporting function was defined that would provide a more robust parametric search capability for Form, Fit, and Functionally (FFF) identical alternatives to discontinued parts. Randy agreed to review the requirement and define when the function could be added. Several other changes to the CSM system were also defined because of the pilot analysis to make CSM more effective for obsolescence management and these were approved for implementation.

In May, Silicon Expert personnel demonstrated their new CSM and BOM cleansing tools. IHS also followed up on their quote for Precience and CAPS Expert evaluation support. Also in May, IHS briefed us on PartNavigator technology available from Precience. It appeared that Precience would provide a valuable integration of several commercial obsolescence tools. Precience promised to provide volume-pricing estimates for their technologies but they were not received.

Arrow Electronics notified Dallas that they were terminating their GIB Ubiquidata service as follows: "We regret to inform you that Arrow Electronics, Inc. will no longer offer the Ubiquidata™ electronic components database or its information services, including Risk Manager, Alert, and Global Explorer™, for commercial sale or licensing. Additionally, the Global Information Business will discontinue its operations. Ubiquidata will remain an important asset of Arrow Electronics for Dallas' core businesses in North America, Europe and Asia, and will be repositioned within Arrow's existing worldwide components businesses in order to optimize the information from the database to support the supply chain needs of Dallas' customers and suppliers." Ubiquidata had proven to be a valuable and extensive source of component data and was particularly helpful in cleansing part numbers. However, based on the status of the service, it was decided to delete GIB from further evaluation under the AOA Pilot. Note that Arrow recently acquired Pioneer Electronics and terminated the Pioneer component database product (StraightLine - Aprisa, Inc) as well. Arrow has thus discontinued two major sources of component information that could have supported the Aerospace industry's management of obsolescence.

It was also decided about this time to recompile and validate separate active and passive component lists for the F/A-22. All input files were located and reorganized in hierarchical fashion by subsystem. The F/A-22 component lists were then analyzed and sorted into active and passive components for each subsystem. A new "PartMaster" database was set up using Microsoft Access database software with tables linked to the subsystem input lists, thus eliminating data entry errors. Using the consolidated list of 158 unique active components, a new LCM report was generated in a DIF format, rather than HTML. This approach analyzes LCM results using Excel to sort and prioritize issues. From Excel tables were set up to link back into Access to extract results by LRU. For the first time, the program was able to analyze all active components from all the F/A-22 subsystems at one time, and parse the results back to the subsystems for further resolution by the programs and their subcontractors. Extra spreadsheets, data ranges, and special logical equations were added to Excel to make the data easier to review and process.

Within minutes, the CSM/LCM tool scanned the list of 158 unique part numbers and found the status of 128 of them (82%). Thus it appeared at first glance that almost 20 percent of the parts numbers were not covered in i2's CSM/LCM data. This seemed higher than expected so the team began verifying and validating the unknown part numbers to see if they should be changed or deleted from the list. The list of unknown parts is shown in Table 8.21.

Table 8.21 - Unrecognized Part Numbers and Corrections

Unknown PN	Correction	Comment
Part # 1	Delete	Internal number not tracked by any tool.
Part # 2	Delete	Internal number not tracked by any tool.
Part # 3	Delete	Internal number not tracked by any tool.
Part # 4	XA	Corrected capitalization error
Part # 5		Valid PN No Correction Recommended
Part # 6	?	Slash typo on suffix should be a backslash (see datasheet) but "\" is not allowed (special character) so use a wild card "?" character.
Part # 7		Ask for orderable part number and manufacturer but changed to a commonly used form.
Part # 8		Inverted description and part number
Part # 9	Delete	Part number correction undetermined.
Part # 10	TA	TA is a 7 inch reel, no TR or TR-ND listed by Zetex
Part # 11	ACQQ	CQQ or ACQQ are correct for certain part numbers, but not for the one requested. Typo corrected.
Part # 12	Delete	The part number correction was undetermined.
Part # 13	INA	LNA suffix not a standard nomenclature
Part # 14	JTX	JTX is short for JANTX
Part # 15	JTX	JTX is short for JANTX
Part # 16	JTX	JTX is short for JANTX
Part # 17	JTX	JTX is short for JANTX
Part # 18	JTX	JTX is short for JANTX
Part # 19	JTX	JTX is short for JANTX
Part # 20	Delete	Part number correction undetermined.
Part # 21	-	Change to slash (/) per data sheet.
Part # 22		Added "-" before the T per data sheet.
Part # 23		The 07 suffix is a non standard package designator which was changed to a similar Agilent product designator for the sake of the pilot.
Part # 24		Typo left out "L" in the suffix corrected
Part # 25	Delete	Part number correction undetermined.
Part # 26		Adding an extra 4 deleted makes this a valid TI part number (suspected typo)
Part # 27	Delete	Discontinued BroadCom part per Arrow tool. Part number correction undetermined.
Part # 28	Delete	Typo added an "L" . Delete since the resulting number is already included on the list.
Part # 29		Corrected to add package type FF designation

As part of the validation process, the unknown part numbers were assessed with other tools and in Internet searches to see if they were valid but missed by the database tool. The PartMiner database and Arrow GIB were helpful in finding similar part numbers but they too had trouble with some of the numbers. We found that in some cases the abbreviated prefix "JTX" was accepted as a valid part number but for other parts the full "JANTX" prefix was required. Correcting the part number to JANTX was sufficient to assure that i2 and other databases recognize the part.

In other cases, a closer examination found that a part number was not identified by any database. Perhaps they were numbers for custom parts rather than a manufacture's orderable part number. Since only a custom database could be expected to track the status of custom parts, these were deleted from the AOA pilot's part list.

Sometimes the part numbers appeared to be in error. Suspected typing errors or transcription errors were corrected to make the number a commercially orderable part. Special characters in some part numbers were changed to a wild card or deleted. If the F/A-22 program could not concur with a correction, the numbers were deleted so that all the tools were required to process only known good numbers.

Even while these part number coverage concerns were being resolved, attention also turned to the implications and accuracy of the data provided. The color-code section of the initial report is shown in Table 8.22.

Table 8.22 - Initial LCM Report Color Codes

PART_NUMBER	COLOR_CODE	PART_NUMBER	COLOR_CODE	PART_NUMBER	COLOR_CODE
Part # 1	YELLOW	Part # 44	YELLOW	Part # 87	GREEN
Part # 2	YELLOW	Part # 45	YELLOW	Part # 88	GREEN
Part # 3	GREEN	Part # 46	YELLOW	Part # 89	YELLOW
Part # 4	GREEN	Part # 47	YELLOW	Part # 90	YELLOW
Part # 5	GREEN	Part # 48	YELLOW	Part # 91	YELLOW
Part # 6	YELLOW	Part # 49	RED	Part # 92	GREEN
Part # 7	YELLOW	Part # 50	YELLOW	Part # 93	RED
Part # 8	YELLOW	Part # 51	YELLOW	Part # 94	YELLOW
Part # 9	GREEN	Part # 52	GREEN	Part # 95	YELLOW
Part # 10	GREEN	Part # 53	YELLOW	Part # 96	YELLOW
Part # 11	YELLOW	Part # 54	GREEN	Part # 97	RED
Part # 12	RED	Part # 55	YELLOW	Part # 98	RED
Part # 13	YELLOW	Part # 56	YELLOW	Part # 99	RED
Part # 14	YELLOW	Part # 57	YELLOW	Part # 100	YELLOW
Part # 15	YELLOW	Part # 58	GREEN	Part # 101	GREEN
Part # 16	YELLOW	Part # 59	GREEN	Part # 102	GREEN
Part # 17	YELLOW	Part # 60	GREEN	Part # 103	YELLOW
Part # 18	YELLOW	Part # 61	YELLOW	Part # 104	YELLOW
Part # 19	YELLOW	Part # 62	GREEN	Part # 105	YELLOW
Part # 20	YELLOW	Part # 63	YELLOW	Part # 106	YELLOW
Part # 21	YELLOW	Part # 64	YELLOW	Part # 107	YELLOW
Part # 22	YELLOW	Part # 65	YELLOW	Part # 108	YELLOW
Part # 23	YELLOW	Part # 66	YELLOW	Part # 109	YELLOW
Part # 24	YELLOW	Part # 67	YELLOW	Part # 110	YELLOW
Part # 25	YELLOW	Part # 68	YELLOW	Part # 111	YELLOW
Part # 26	YELLOW	Part # 69	YELLOW	Part # 112	YELLOW
Part # 27	YELLOW	Part # 70	YELLOW	Part # 113	YELLOW
Part # 28	YELLOW	Part # 71	YELLOW	Part # 114	RED
Part # 29	YELLOW	Part # 72	YELLOW	Part # 115	GREEN
Part # 30	YELLOW	Part # 73	YELLOW	Part # 116	YELLOW
Part # 31	YELLOW	Part # 74	GREEN	Part # 117	YELLOW
Part # 32	YELLOW	Part # 75	YELLOW	Part # 118	YELLOW
Part # 33	YELLOW	Part # 76	YELLOW	Part # 119	YELLOW
Part # 34	GREEN	Part # 77	YELLOW	Part # 120	YELLOW
Part # 35	YELLOW	Part # 78	YELLOW	Part # 121	RED
Part # 36	YELLOW	Part # 79	YELLOW	Part # 122	YELLOW
Part # 37	RED	Part # 80	YELLOW	Part # 123	YELLOW
Part # 38	YELLOW	Part # 81	YELLOW	Part # 124	YELLOW
Part # 39	YELLOW	Part # 82	YELLOW	Part # 125	YELLOW
Part # 40	YELLOW	Part # 83	YELLOW	Part # 126	YELLOW
Part # 41	YELLOW	Part # 84	YELLOW	Part # 127	YELLOW
Part # 42	YELLOW	Part # 85	YELLOW	Part # 128	YELLOW
Part # 43	YELLOW	Part # 86	YELLOW		

Even though these were parts from current production designs of the newest Air Force fighter, the initial assessment of four subsystems found nine Red parts, parts with no current source of supply. This information was fed back to the F/A-22 program and they began immediately to confirm the information and resolve confirmed issues. After determining which F/A-22 subsystems used these red parts, the program contacted the appropriate subsystem suppliers and began working to locate residual inventory or alternative parts to meet near-term requirements. For the longer term, the F/A-22 program also assessed the need for upgrades and/or redesigns to mitigate risks.

In addition to the nine RED parts, the initial assessment also identified 100 yellow parts; i.e., parts with a single source of supply. Twenty-two of these sole source parts were late in their respective life cycle (Decline or Phase Out) and thus soon to become obsolete. Significantly, the manufacturers of four yellow parts had already announced last time buy (LTB) dates. Thus the CSM/LCM tool quickly identified about twenty sole-sourced parts that were high-risk items and soon to be discontinued. While most (about 75) sole-sourced parts were medium risk, only three sole-sourced parts were in their low-risk "Introduction" or "Growth" phases so the obsolescence risk level for the AOA part list was primarily medium or higher.

To confirm these findings and better understand the data quality provided by the CSM/LCM data system, the AOA pilot team began comparing the CSM/LCM findings with the obsolescence data from other tools. Marietta's F/A-22 obsolescence management personnel generated a TACTRAC Risk Analysis Report to compare with the CSM/LCM report. Similarly, Dallas personnel processed the same list with Arrow's Ubiquidata and Total Parts Plus to assess the relative agreements in obsolescence status of the parts.

Initial efforts on the AOA pilot included updating Dallas' contacts with the other tool alternatives to be evaluated in conjunction with i2's LCM. For example, the AOA pilot met with Jerry Schroeder, the local rep for Arrow's database tools. He presented results of an evaluation a few parts that were obsolete in LCM. In most instances, the Arrow data agreed with Dallas' LCM data. However, Dallas Component Engineering identified a few disparities. After this meeting, Jerry provided a quote for an evaluation subscription to Arrow's services during the AOA pilot.

Therefore, in the first quarter of 2003 the Dallas POMTT Pilot Program began to assess and compare the obsolescence data capabilities of i2's LCM content in Dallas' CSM system with that of other alternatives. The AOA Pilot started with the implementation and testing of Dallas' CSM interface to LCM content. Dallas finalized a licensing approach for LCM Content data so that Marietta can use Dallas' CSM/LCM system via Dallas' Intranet. They also began reviewing and setting up licenses for other tools from GIDEP, Arrow/Avnet, MTI, SiliconExpert, etc.

At the next POMTT Program Review Lockheed Martin Aeronautics Company - Marietta and the F/A-22 SPO attended as participants in the newly authorized F/A-22 AOA Pilot. George Sacarelos represented LMAC while Jason Cornelli represented the F/A-22 SPO. This strong support from Dallas' F/A-22 pilot partners indicated the value and level of interest they placed on the Dallas AOA Pilot. Specific words of praise were received from the F/A-22 SPO who stated only contractor input he ever received was when an obsolete part was identified and that funding was needed to affect a solution. He also stated that this was the first time he had ever seen this much progress on a solution for a program and industry-wide problem.

A review of data from GIDEP found that at least some of the items on a GIDEP posting of Texas Instruments' most recent list of discontinued parts still showed some as "active" in some tools. One goal of the AOA Pilot is to assess whether component discontinuances that are announced by manufacturers and/or distributed by GIDEP can be used to determine data latency in LCM and other obsolescence tools. A process of measuring latency for LCM and other tools was explored and IT was advised of Dallas' intent to measure this metric so that Dallas' CSM system is kept up to date. The LCM data updates would be made weekly to help ensure this potential problem was held at a minimum.

Aprisa, IHS and Silicon Expert tools were also reviewed and the POMTT program confirmed that the Total Parts Plus licenses for MLRS could be used on a non-interference basis during the AOA pilot. Chuck Reusnow provided two lists of parts that were processed using the CSM/LCM tool. Several of the parts numbers provided needed to be corrected but most of the common IC's and actives were assessed. The results were provided to Reusnow and discussed briefly.

To maintain close coordination and kick off the study effort, a meeting was scheduled for early February. This meeting will focus on resolving remaining tool licensing and access issues and on the exchange of component data with the F/A-22 program.

Therefore, by the end of the second quarter of 2003 significant accomplishments included:

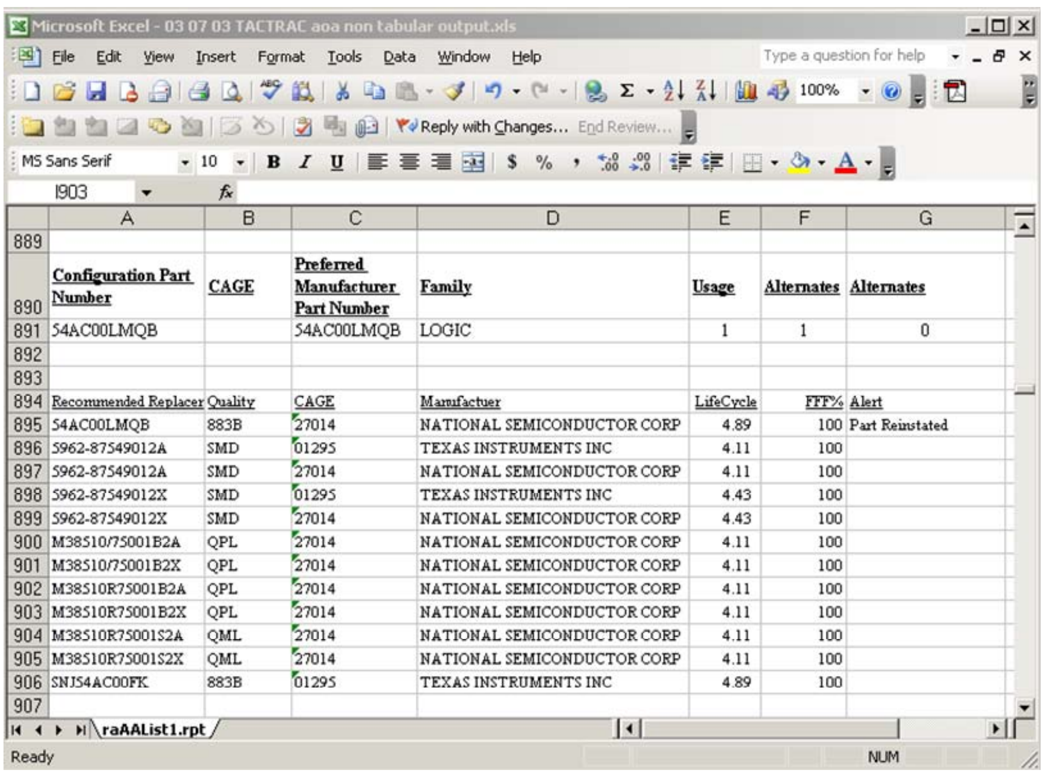
- Set up CSM client software for Marietta and tested the interface.
- Procured licenses and tested the interface to the Arrow Global Information Business (GIB) Ubiquidata tool.
- Performed an initial assessment of three F/A-22 electronic subsystem's components using both Life Cycle Management (LCM) and Ubiquidata tools.
- Finalized licenses for Information Handling Services (IHS) and MTI tools.

The F/A-22 Automated Obsolescence Assessment pilot also made rapid progress as late in the quarter George Sacarelos had the CSM client installed on his laptop. The interface was then tested through Dallas' local network; dial-up modem access and a remote DSL connection and the system seemed fully functional in all modes. For the first time a Lockheed Martin program from outside Missiles and Fire Control was able to use the CSM system and LCM search tool. Comparative testing had also begun with the Ubiquidata system, Silicon Expert, IHS, i2, MTI, and Arrow's GIB.

Each of the tested obsolescence tools has a different user interface and provides different types of obsolescence data with different reports and screen presentations.

Thus comparison of results requires interpretation. For example the TACTRAC report provided by the F/A-22 program listed a lifecycle score to three significant figures for each part number. These scores ranged from 1 to 5 indicating the related lifecycle status from early introduction to obsolete. A part number may have more than one source that is considered at the same or different product lifecycle stages but additional processing would be required to determine if the part is single sourced. TACTRAC does not provide explicit RED, YELLOW or GREEN status to indicate availability from none, one or more than one source.

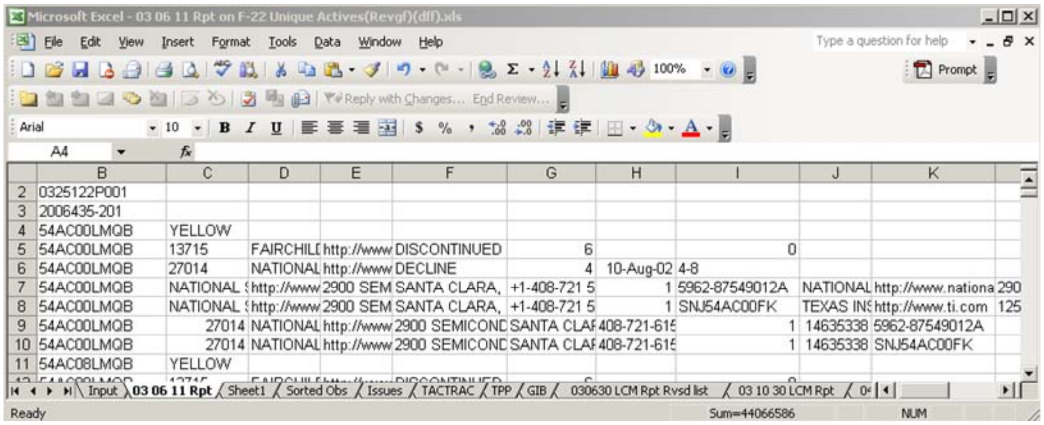
A typical TACTRAC risk report screen for example part number 54AC00LMQB is shown in the Figure 8.64. TACTRAC generated 59 pages of report for the AOA part list. One notes that the only source of the stated part number is National and its lifecycle code is 4.89 (where 5.00 is obsolete). However an alternate part, the SMD version, may be available from both National and TI and the SMD version has a better lifecycle code of 4.11.



	A	B	C	D	E	F	G
889							
890	Configuration Part Number	CAGE	Preferred Manufacturer Part Number	Family	Usage	Alternates	Alternates
891	54AC00LMQB		54AC00LMQB	LOGIC	1	1	0
892							
893							
894	Recommended Replacer	Quality	CAGE	Manufactuer	LifeCycle	FFF%	Alert
895	54AC00LMQB	883B	27014	NATIONAL SEMICONDUCTOR CORP	4.89	100	Part Reinstated
896	5962-87549012A	SMD	01295	TEXAS INSTRUMENTS INC	4.11	100	
897	5962-87549012A	SMD	27014	NATIONAL SEMICONDUCTOR CORP	4.11	100	
898	5962-87549012X	SMD	01295	TEXAS INSTRUMENTS INC	4.43	100	
899	5962-87549012X	SMD	27014	NATIONAL SEMICONDUCTOR CORP	4.43	100	
900	M38510/75001B2A	QPL	27014	NATIONAL SEMICONDUCTOR CORP	4.11	100	
901	M38510/75001B2X	QPL	27014	NATIONAL SEMICONDUCTOR CORP	4.11	100	
902	M38510R75001B2A	QPL	27014	NATIONAL SEMICONDUCTOR CORP	4.11	100	
903	M38510R75001B2X	QPL	27014	NATIONAL SEMICONDUCTOR CORP	4.11	100	
904	M38510R75001S2A	QML	27014	NATIONAL SEMICONDUCTOR CORP	4.11	100	
905	M38510R75001S2X	QML	27014	NATIONAL SEMICONDUCTOR CORP	4.11	100	
906	SNJ54AC00FK	883B	01295	TEXAS INSTRUMENTS INC	4.89	100	
907							

Figure 8.64 - Typical TACTRAC Risk Report

The data from the CSM/LCM report on the same component is shown in Figure 8.65. The LCM Report is not as robust in showing alternates but it shows the predecessor device from Fairchild and shows readily that the part is sole source from National. Rather than listing alternates like TACTRAC, the CSM/LCM system provides a robust parametric search function. To find parts with similar characteristics, CSM/LCM produces upgrade, downgrade, and generic device number searches for alternatives to a given part. In our LCM report, a limited list of supplier recommended alternates is listed in addition to the CSM/LCM capability to look for alternates via robust parametric data. This parametric search function is not provided by most other obsolescence tools.



	B	C	D	E	F	G	H	I	J	K	
2	0325122P001										
3	2006435-201										
4	54AC00LMQB	YELLOW									
5	54AC00LMQB	13715	FAIRCHILD	http://www	DISCONTINUED	6		0			
6	54AC00LMQB	27014	NATIONAL	http://www	DECLINE	4	10-Aug-02	4-8			
7	54AC00LMQB	NATIONAL S	http://www	2900 SEM	SANTA CLARA,	+1-408-721 5	1	5962-87549012A	NATIONAL	http://www.nationa	290
8	54AC00LMQB	NATIONAL S	http://www	2900 SEM	SANTA CLARA,	+1-408-721 5	1	SNJ54AC00FK	TEXAS INS	http://www.ti.com	125
9	54AC00LMQB	27014	NATIONAL	http://www	2900 SEMICOND	SANTA CLAR	408-721-615	1	14635338	5962-87549012A	
10	54AC00LMQB	27014	NATIONAL	http://www	2900 SEMICOND	SANTA CLAR	408-721-615	1	14635338	SNJ54AC00FK	
11	54AC08LMQB	YELLOW									

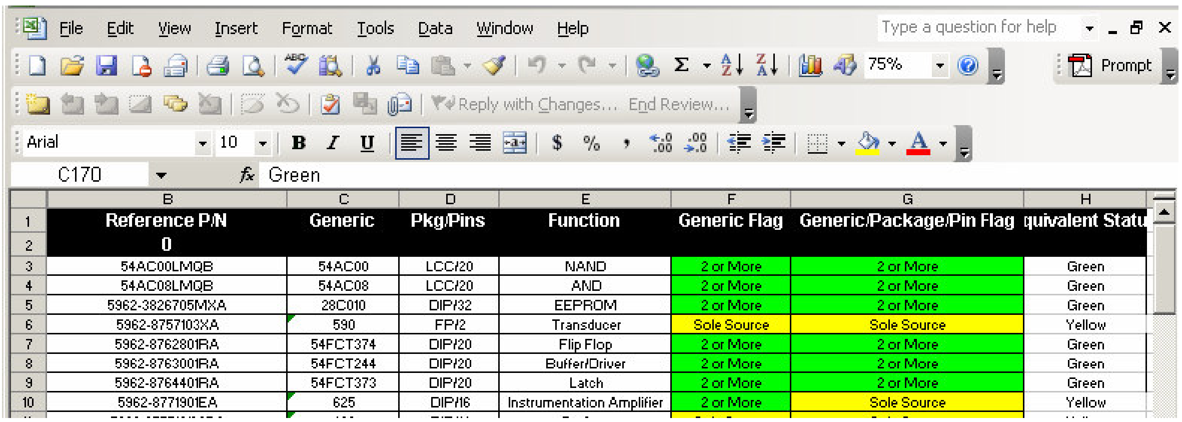
Figure 8.65 - Typical CSM/LCM Data

The Arrow Global Information Business (GIB) Ubiquidata report provided the risk data shown in Figure 8.66. Unlike TACTRAC and CSM/LCM, Arrow indicated that this part is multi-sourced and part availability risk is Low. However, Arrow requires that part numbers be coupled with a supplier in its database. Obtaining the information about other sources of a part that has more than one supplier was quite difficult with this constraint.

	A	B
1	Supplier Part Number	54AC00LMQB
2	Supplier Name	National Semiconductor
3	Part Description	Quad 2-Input NAND Gate
4	Status	Valid
5	Price Per Unit	N/A
6	Requested Quantity	1
7	Requested Date	06/30/2003
8	Extended Price	N/A
9	Availability Notes	
10	Family Life Cycle	M=Mature
11	Family Life Cycle (Risk Value)	3-Low
12	Part Availability	S=Standard/Active
13	Part Availability (Risk Value)	3-Low
14	Multi Source Profile	D=Dual-sourced
15	Multi Source Profile (Risk Value)	2-Medium
16	Breadth of Usage	S=Sparse-Usage
17	Breadth of Usage (Risk Value)	1-High
18	Lead Time	7

Figure 8.66 - Typical Data from Arrow Ubiquidata

Total Parts Plus also reported that the part has two or more sources as seen in Figure 8.67. This is probably true for the die and package but not for the specific orderable part number with the specified lead finish, package, qual level, and temperature range. As is often the case, both the definition and the data for risk and availability varies from tool to tool and must be confirmed by manually by calling the suppliers and double checking the status on parts with near-term impact on mission success.



Reference P/N	Generic	Pkg/Pins	Function	Generic Flag	Generic/Package/Pin Flag	quivalent Statu
0						
54AC00LMQB	54AC00	LCC/20	NAND	2 or More	2 or More	Green
54AC08LMQB	54AC08	LCC/20	AND	2 or More	2 or More	Green
5962-3826705MXA	28C010	DIP/32	EEPROM	2 or More	2 or More	Green
5962-8757103XA	590	FP/2	Transducer	Sole Source	Sole Source	Yellow
5962-8762801RA	54FCT374	DIP/20	Flip Flop	2 or More	2 or More	Green
5962-8763001RA	54FCT244	DIP/20	Buffer/Driver	2 or More	2 or More	Green
5962-8764401RA	54FCT373	DIP/20	Latch	2 or More	2 or More	Green
5962-8771901EA	625	DIP/16	Instrumentation Amplifier	2 or More	Sole Source	Yellow

Figure 8.67 - Typical Data From Total Parts Plus

After the initial assessments with CSM/LCM and other tools, the pilot team updated the list of part numbers to contain 146 known good part numbers and reran the reports for those parts using CSM/LCM, Total Parts Plus, Arrow, and TACTRAC. The results were compiled and coverage by each tool was calculated in Table 8.23 as follows:

Table 8.23 - Initial LCM Report Color Codes

Tool	Parts Found	Percent
CSM/LCM	144	98.6
TACTRAC	139	95.2
Total Parts Plus	141	96.6

Thus early in the study, each of the database tools had excellent coverage. All three tools identified at least 95 percent of the parts on the AOA's validated part list and were in general agreement regarding the lifecycle status of the parts. Most users would consider this performance adequate if the number of parts being tracked is a few hundred or less (typical of a system or subsystem). However, at and enterprise level, the number of parts being tracked by a tool is usually several thousand or even several tens of thousands of unique part numbers. At quantities quantity, the number of unidentified parts that must be assessed manually would require significant effort and expense.

Although the exact savings achieved by selecting a more robust data source is dependant on many factors, potential savings are significant. For example when a tool is used to assess and managing information on 10,000 parts, we could save the effort required to do a monthly manual assessment of only 100 (1%) rather than 500 (5%) unidentified parts. If the effort is only 15 minutes per part per month, to assess 400 extra parts would require 100 man hours per month or about 1200 hours per year. At $100 per man hour (a conservative estimate), this effort would cost $120K per year. This approach would also require developing and maintaining a custom interface between the component data system and an external obsolescence data source. The cost for developing custom implementations is estimated to be $100K to $500K depending on the complexity of the systems and maintaining them could cost from $20 to $100K per year.

The cost of the LCM data subscription for the CSM system is about $100K per year but its interface with the CSM data system was a standard i2 implementation that did not require customization or additional maintenance. While the subscription is about two or three times higher than other data sources like Total Parts Plus, TACTRAC or Ubiquidata that typically cost $30 to $50K per year per user, only one license was required for all programs and users in the Lockheed Martin Missiles and Fire Control enterprise. At the enterprise level, having an integrated system that allows rapid access for hundreds of users to more complete data is of great value and saves significant effort required to manage unidentified parts and a complex database interface.

In summary, thirteen discontinuances were identified that impact four F/A-22 subsystems during Phase 1. Also found were four single-sourced parts to be under a life-time-buy alert. Within the original list of 158 unique active parts, 28 of the part numbers were unidentified and thus needed corrections or validation. This data was provided to George Sacarelos and he began working with his subcontractors to resolve impending issues and cleanse part numbers that were not recognized as valid. George also began identifying alternate parts for obsoletes using CSM/LCM and TACTRAC and found some variability between LCM and TACTRAC. This was investigated further using the Total Parts Plus, Arrow Ubiquidata, PartMiner and SiliconExpert tools.

8.5.4.2 <u>Phase 2 Data Collection:</u>

By the third quarter of 2003 the AOA Pilot Program was well underway. Significant accomplishments included:

- Completed Phase 1 assessment of LCM and compared it to results from other tools including Total Parts Plus, Ubiquidata and TACTRAC.
- Found that all tools did a relatively good job (above 60% coverage) of assessing the F/A-22 active components but LCM produced superior results.
- Updated the LCM tools for researching and scrubbing part numbers.
- Explored adding Precience, Promiere and other tools to the second phase of the pilot.

On July 1 2003, i2's Todd Meadows (i2) visited Lockheed Martin to continue discussions and define functional interfaces that would expedite the evaluation of obsolete parts and the identification of FFF alternates using CSM. A very beneficial interchange between Todd and Randy Washburn (M&FC IT) resulted in new insights and understandings for both. Todd offered to continue working together to make sure the CSM system is being used fully during the AOA Pilot.

A Beta test license was received from IHS for CapsXpert and Precience for PartNavigator and AMLNavigator. Dallas also discovered another component technology database tool called netCOMPONENTS, Inc. (http://www.netcomponents.com). While waiting during a SLTA pilot delay, Trey Fixico began developing a Visual Basic interface to the off-site obsolescence tools. He was able to set up a browser that automatically logs into the GIB web site.

By mid-July, preliminary results were being compared and used to improve Dallas' tools for the second half of the Pilot. The same representative list of "active" electronic parts from the four F/A-22 subsystems was assessed using TACTRAC, Total Parts Plus and CSM/LCM. After eliminating parts numbers that were not recognized by at least one system, all the tools provided 95% coverage or better. Total Parts Plus was about 2% more complete than TACTRAC while LCM obsolescence coverage was about 2% better than Total Parts Plus. For a small number of parts (under 1000) this could be an insignificant difference. However, on an enterprise-wide basis with over 200,000 parts to monitor, manual assessments of an additional 4000 parts (2%) quarterly would require a large and expensive manpower commitment. Cost avoidance for a large enterprise like Lockheed Martin could easily exceed $2M per year.

To facilitate assessment of a larger list of part numbers, automation of data collection continued to be improved. The automated log was demonstrated for multiple sites and began defining the data download process. M&FC-D also obtained access to Prescience's PartNavigator software with IHS content and to AVNET's online component database with i2 content. Initial testing on these tools began and it was found the AVNET interface is quite similar to Dallas' CSM system.

At a request from POMTT, Randy Washburn developed and began testing four new enhanced report functions for the CSM system as the result of previous improvement suggestions from the pilot. These reports expanded CSM's ability to research difficult part numbers. Now users can rapidly check a list of parts using an increasingly broadened search for alternates and information. The three most restrictive automated searches are based on i2's FFF codes, function codes and generic numbers. Any part numbers on the initial input list produces an output list of other parts that have identical parameters; i.e., FFF code, Function code or generic number. Thus with a simple user-controlled process, the report lists alternates to an obsolete part number from both the commercial and military partitions of the i2 database. If available, the report also lists status and lifecycle data for the parts. The fourth (and the broadest) search function looks for related part numbers by iteratively truncating the suffix of the original part number, one character at a time. This "truncation" report produces useful clues to information about obsolete or erroneous part numbers and helps the user to "scrub" part number errors. Testing of these functions will continue but, in initial trials, several part numbers were identified that had been unidentified by previous techniques.

In late July, Arrow rescinded their earlier discontinuance announcement and announced that they had decided to continue to sell and maintain the Ubiquidata component database product. While some features will not be carried forward, most of the tools capability will continue to be available under subscription service for Arrow's customers. Dallas reconsidered refocusing Dallas' evaluation of Ubiquidata during the remainder of the AOA Pilot. Thus, the tool will continue to be evaluated during the remainder of the AOA Pilot.

The program met with LMM&FC's Steven Bell to review how he uses Total Parts Plus (TPP) to identify and assess MLRS program obsolescence issues. He indicated that he seldom uses LCM Report but rather uses TPP to monitor last time buy dates and other changes on his list of about 1000 M270 parts. POMTT then demonstrated how to get a similar report from CSM by requesting the report in DIF format and then copying and sorting LCM data by LTB date. MLRS continued to explore use of the CSM/LCM system after better understanding the use of the system.

By the fourth quarter 2003 the AOA project team had completed updates of the tools under review and began to focus primarily on Phase 2. This consisted of comparisons of LCM other tools including Total Parts Plus, QTEC, Ubiquidata and TACTRAC. The program also continued to investigate other new component technology databases like i2's "4Donline™ Parts Universe™, netCOMPONENTS, Inc. and QTEC's new Q-Star tool. For example, an on-line demonstration was provided on QTEC's new Q-Star tool for the Lockheed Martin CTI Working Group. Mal Baca (formerly with TacTech) presented Q-Star capabilities and set up a trial subscription with George Sacarelos as Administrator. George set up access for about 30 Lockheed Martin obsolescence experts to try out the QTEC tool. During the meeting the AOA pilot loaded a list of about 150 parts and found that Q-Star provided immediate coverage for about 75% of the parts. This compared unfavorably to over 95% for Total Parts Plus, TACTRAC and LCM. However, within a few days QTEC had rapidly addressed the unrecognized parts and reduced the unrecognized parts to about 5%. This level of commitment and service is rare in the industry since most tools require the user to identify missing data and inconsistencies. The tool appeared to be quite intuitive and easy to use and appropriate comparisons of coverage and accuracy for QTEC and i2 products would continue.

On 24 September, the F/A-22 program asked for the status of a part (SWD109-PIN) that one of their subcontractors had recently determined to be discontinued. The part was shown to be "active" in the databases at i2, TacTech, Total Parts Plus and Arrow while F/A-22 had already confirmed that the part was not listed in the QTEC database. Thus, it appears that the status of this part is not correctly listed in any of the major databases. i2 was notified to correct this condition but the problem illustrated that the breadth of the issue (other parts similarly wrong in status) is difficult to determine. The LTB date for this particular part was 30 May 2003, so its discontinuance notice was probably about a year ago. The team was finally able to locate the discontinuance notice from the manufacturer (M/A-COM) and found that no other obsolete parts were similarly affected.

M/A-COM did, however, provide a list of about 1100 other parts that were transferred (sold off and discontinued by M/A-COM) and these are still being shown as “active” M/A-COM parts in the i2 database. i2 was again notified of the issue. It appeared that keeping an accurate status record on millions of active and passive electronic components would be beyond the ability of all the major database tools providers.

While the cost of an urgent subsystem redesign and requalification is high, it pales when compared to the cost of stopping the production line or grounding aircraft. Exact delays and costs are highly variable depending on the component affected and the complexity of the mitigation task. A typical two-year redesign and requalification of a subsystem could easily cost $5M. However, the cost of delaying the delivery of twenty $200M aircraft for two years would be far greater. Also the related cost impact on operations for revised training, support tooling and spare parts for the resulting multiple as-built configurations grows rapidly. Such costs could conservatively multiply the cost of the redesign by a factor of 10. In short, avoiding surprises in the availability of parts has great benefit in total ownership costs of a system and is essential for maintaining high system availability.

8.5.5 <u>Summary Data Analysis:</u>

AOA Pilot data was collected over a several months. The results of this analysis are segmented into the initial “early” phase and the “continuing” phase.

In obsolescence management, available resources are typically focused toward determining status on high-risk items. Complex electronic components like processors and other microcircuits tend to have the most rapid technical evolution and thereby, the highest obsolescence risk. Simpler active (transistors, diodes, etc.) and passive (resistors, capacitors, connectors, etc.) components have lower risk and that risk is usually easier to mitigate. Thus programs focus first on the determining and verifying obsolescence status of high-risk, high-impact components.

Similarly the F/A-22 AOA Pilot team focused first on exploring and verifying risk and status information for both the RED parts and Yellow parts that have LTB dates (Y/LTB). The initial LCM assessment found 14 parts high-risk parts with RED or Y/LTB status. Thus about 10% of the sample part list had critical issues. One part, shown as YELLOW in LCM, was shown as RED in Total Parts Plus (MT55L512Y36FT-10). Table 8.24 compares the initial obsolescence risk ratings found for these 15 parts in each of four tools.

Table 8.24 - Early Tool Comparison

PART NUMBER	LCM	TACTRAC	Arrow	TPP
5962-8946801XC	Y/LTB	4.9	Y/LTB	Y/LTB
5962-9211601HZA	Red	3.84	NoID	Green
AT17LV020-10JI	Y/LTB	4.9	Y/LTB	Y/LTB
E28F128J3A-150	Red	5	Yellow	Yellow
FMMT3904TA	Red	3.87	Yellow	Yellow
IDT74ALVCH16827PF	Y/LTB	4.9	Yellow	Green
IDT74LVC863APG	Red	5	Yellow	Yellow
MT55L512Y36FT-10	Yellow	NoID	Yellow	Red
NC7SZ126M5	Red	5	Yellow	Yellow
QS32XVH245Q2	Red	5	NoID	NoID
QS5V993-5QI	Red	5	NoID	Yellow
RF1S30P06SM	Red	5	Yellow	Red
TC58512FT	Red	1.11	Yellow	Yellow
X9C103DM	Red	5	Red	Yellow
XC40150XV-09HQ240I	Y/LTB	4.9	Y/LTB	Y/LTB

Note: Data highlighted in red or yellow seem to be in error or questionable, respectively.

Several interesting observations emerged from this tool comparison:

1. Seven of the ten RED parts in LCM (70%) were confirmed by at least one of the other tools while only one of these ten parts (X9C103DM) was confirmed by at least two other tools.
2. Three of four Y/LTB parts (75%) were confirmed by all four data tools indicating that current production parts with near term issues are more consistently tracked by the tools than discontinued parts.
3. The one remaining Y/LTB part, the IDT74ALVCH16827PF, was later confirmed to be out of production so it appears that Arrow and Total Parts Plus failed to identify the high-risk of this part's status.
4. TACTRAC, Arrow and Total Parts Plus disagreed with CSM/LCM about the TC58512FT RED status. Later i2 changed its status to YELLOW and availability was further confirmed by QTEC. However the very low value of 1.11 for the TACTRAC code seems to be dubious.
5. Two other part numbers, 5962-9211601HZA and FMMT3904TA, continued as RED in CSM/LCM until the end of the Pilot. That information remained unconfirmed by the other tools and it was later confirmed that both parts are

still available but the ZETEX FMMT3904TA remains available only "while supplies last." Thus the LCM RED status was in error and the TacTech code of 3.87 seems doubtful.

6. The MT55L512Y36FT-10 was RED in Total Parts Plus, not found in TACTRAC and Yellow in Arrow and CSM/LCM. CSM/LCM continued to show the MT55L512Y36FT-10 to be in production by Cypress (Yellow) with 4-8 years of availability at the end of the pilot. However, this appears to be incorrect since Total Parts Plus RED status was later confirmed; i.e., that the Cypress part is discontinued and available only "while supplies last."
7. Even obsolescence data from the same company, namely CSM/LCM and TACTRAC from i2 Technology, did not provide consistent status information.
8. A 80 percent data validity rate for high-risk parts appears to be the best available among the major obsolescence database tools that the AOA Pilot examined.

In summary, the continuous tracking of status for millions of electronic components from hundreds of manufacturers appears to so difficult that none of the tools were adequately correct about the obsolescence status of the most-important, high-risk items in current production assemblies like those in the F/A-22.

8.5.6 <u>Continuing Observations</u>

While during early analysis, the AOA pilot found that, while basic part coverage was good (over 95% for active components) in the four tools examined, when assessing the obsolescence of high priority systems, the AOA pilot team found that multiple sources of information were required to accurately identify the critical issues. With only one tool, an obsolescence manager should only expect to identify about 50 to 80% of the high-risk items. Assuming that about 5% of the parts in a monitored list will become DMSMS issues each year, about 50 components per year would become an issue for a program with 1000 unique part numbers being monitored. With only one source of data, about 10 of these DMSMS issues should be expected to go unidentified each year until they require aftermarket procurement or some more expensive mitigation technique. Each additional independent source of obsolescence data would, based on this study's observations, reduce the number of items missed by 50 to 80%. Thus adding an extra obsolescence tool should result in 5 to 8 of the items missed by the first tool being identified while supplies are still available.

Aftermarket recurring costs for components are estimated by DMEA to be 5 to 10 times the baseline cost. Thus assuming an average baseline cost per part of $50, the typical program will spend and extra $200 to $450 per item if a part must be sourced from the aftermarket. This is likely a conservative assumption since for the four items on last time buy during the early phase of the program, approximate prices were $1.91, $38, $452 and $1230 (an average price over $430 rather than $50) for quantity 500.

The estimated cost avoidance from having extra sources of obsolescence status data depends on the cost of the extra tool subscriptions and the quantity of parts needed to meet future requirements. If one assumes that a part is used 10 places in a system and 100 systems per year are fabricated, the part consumption requirement is 1000 parts per year. For ten years of continued production, a program would require an advanced lifetime buy of 10,000 parts. Any requirements for spare parts, process losses, scrap or repair/support needs would be in addition to this. If not bought from the original source, this results in an aftermarket cost penalty of from $2 to $4.5 million per part. For a program to use the aftermarket on 10 missed DMS parts per year, a penalty cost of $20 to $45 million results. Since each source of DMSMS data is typically only about $50k per year, it is clear that procuring multiple sources of data is a cost effective way for Lockheed Martin to minimize the occurrence of aftermarket sourcing penalties or other, even more expensive, DMSMS correction alternatives like emulation or custom fabrication.

From the AOA pilot it therefore appears that the status of electronic components should be assessed by multiple sources of data to avoid tedious and expensive manual confirmation with the manufacturer. The use of multiple tools speeds the process of verifying information and finding alternative or replacement parts for confirmed DMS issues that would otherwise be missed. Hence there is significant benefit for combining several obsolescence data sources like status tracking tools, prediction tools and comprehensive parametric component data tools. For an enterprise with ten programs or the DoD with thousands of programs, significant costs can be avoided by maintaining active DMSMS management with enough data sources to prevent most mitigation penalties. Since the F/A-22 has many more than 1000 electronic components in its subsystems and since production and sustainment requirements are often significantly more than 10,000 units of each DMS item, F/A-22 program losses from not implementing AOA's recommended multiple-tool approach could easily exceed $100M per year.

As the study continued, several obsolescence data services began to compete with i2, MTI and Arrow and were reviewed briefly during the AOA pilot. These new tools included

1) Avnet Promiere
2) Prescience PartNavigator with IHS CAPS Expert™ data
3) QTEC Q-Star™
4) SiliconExpert

These alternatives are less well known than TacTech, Total Parts Plus and i2 and will be described briefly here.

Also during the continuing study, Arrow consolidated their GIB holdings and eliminated Ubiquidata as a product. By the end of the study, Arrow decided to continue to provide some obsolescence data on components but only with a reduced scope compared to Ubiquidata. Although Ubiquidata was fast, user friendly and uniquely coupled to Arrow's internal inventory and pricing data, after the licenses for Arrow Ubiquidata expired at Lockheed Martin Missiles and Fire Control, they were not renewed and the tool was dropped from further evaluation during the AOA pilot.

8.5.6.1 Promiere

The study team discovered Avnet Promiere (http://www.promiere.com/index.jsp) began providing obsolescence and component data late in the AOA Pilot study. Their online information about the "Component Selector" tool states:

Component Selector, powered by i2®, provides optimization of the component selection process by providing a single product catalog for more than 9 million electronic components from more than 500 manufacturers in 350 categories. The ability to identify and compare parts by description, including predictive life cycle information, offers incredible ease of use and flexibility. With the component selector database, you can quickly and confidently identify and minimize component obsolescence problems and improve design engineering and sourcing processes which enable faster time-to-market, decreased design cycle time, increased profits, and increased customer satisfaction.

Thus, the AOA pilot found that Avnet is using i2's component data and lifecycle data in Promiere Component Selector/BOM Optimizer. Pricing for this service was under $20k per year and was selected by the Lockheed Martin Sunnyvale site to provide data to their in-house component databases. In fact, for a single named user with less than 5000 parts, the price is only $5000/yr. While this approach offers the same data that i2's CSM system provides, it is done via a web interface so part list data does not remain behind the company firewall. This remains a security issue and prevents Promiere from being easily integrated with CAE, ERP, and PDM tools the way that i2 CSM/LCM is implemented. Thus the AOA pilot found that the Avnet Promiere data quality is essentially the same as CSM/LCM but data security is a significant consideration in tool selection. At a cost of under $20k per year, Promiere is an effective way to obtain access to i2's data without the implementation cost ($2M, typ) of a custom designed and integrated component supplier management (CSM) system.

8.5.6.2 PartNavigator

IHS (http://www.ihs.com) has been providing technical data to the defense industry for many years. IHS provides electronics component technical data, pricing and availability information is primarily through CAPS Expert™ and the PartMiner CAPS™ Database. Aspect development, the original developer of i2's CSM/LCM tool, licensed and integrated IHS data with their system when it was initially deployed as CSM in Dallas. This was prior to Aspect developing their extensive electronic component parameter database or the subsequent LCM lifecycle database.

CAPS™ was designed to provide engineers a comprehensive source of technical data and to connect sources with buyers of components. As their name indicates, PartMiner focuses particularly on locating "hard-to-find, obsolete, and shortage parts for customers." While the parts have some parametric data to allow searches for alternates based on performance requirements, other tools including i2's and SiliconExpert's have more robust parameterization and thus provide superior parametric search capabilities for engineers.

In PartMiner, the user enters a part number (one at a time) into the CAPS™ Expert on-line web interface to do “research” on the part and its availability and price. Depending on the subscription level of the user, the system rapidly provides technical data along with pricing and availability on all parts with a similar part number. For individual named users, the annual subscription to CAPS Expert™ is under $6000 while a site license is under $40k. More robust versions of the interface are also available that allow the user to enter lists of parts for analysis.

Precience developed PartNavigator and AMLNavigator to use IHS component data (and/or other data sources) to provide component status data to an enterprise much as i2’s CSM does. Thus Precience provides a customized database that uses content from other sources. The PartNavigator tool provided an interface in which allows part lists or single part numbers to be loaded and their status assessed rapidly. The PartNavigator interface was intuitive and easy to understand. The AOA Pilot found that IHS/Prescience tools are a good choice, especially for integrated enterprise systems that need tight CAE, ERP or PDM integration. The IHS data is a robust source of part data especially for older designs where its legacy component data is the most complete we observed.

8.5.6.3 Q-Star™

QinetiQ Technology Extension Corporation (QTEC) (https://www.qtec.us) is the US subsidiary of QinetiQ Group plc. QTEC was founded by the developer of TacTech, Mal Baca, after his non-compete agreement with i2 expired. Most of the former staff at TacTech also joined with Mal to develop the QTEC obsolescence database. Q-Star™ was designed from the ground up to be an obsolescence tool rather than a design tool with obsolescence data. Therefore part data is not parameterized to allow the user to search for components by key performance parameters.

However, Q-Star™ provides a robust tool for obsolescence managers that want to know current availability, lifecycle status, years of remaining life for a large structured part list. It is designed to facilitate collaboration. For example, part status and utilization data are easily shared with other programs inside the firewall. Outside the firewall, customers can implement coordinated efforts between programs that use the same parts and Lockheed Martin supplier part lists can be coordinated to achieve economies of scale in the mitigation of DMSMS issues.

Although just a startup during 2003, QTEC was able to implement a robust online obsolescence tool, Q-Star™. In late 2003 the DoD DMSMS Center of Excellence (www.dmsms.org), selected Q-Star™ to be their obsolescence database. Thus Q-Star™ is now available to all DoD services and programs at no additional charge and is rapidly becoming a part of the DMSMS management toolkit at major DoD contractors. For Lockheed Martin and other DoD prime contractors, the Q-Star™ system is offered as an online tool for about $40k per year per site. For large primes with many sites, multiple site and enterprise discounts apply that could achieve costs well under $1000 per year per user. As appropriate, large companies can also set up a private and public database to minimize exposure of some part lists to online access while providing access to customer and supplier personnel if appropriate. QTEC also offers reduced cost licenses to small suppliers of major contractors to facilitate collaborative efforts on DMSMS issues by even the smallest of subcontractors.

The Q-Star™ product is new to the DMSMS market and tended to be a limited but rapidly expanding compilation of component status data. For example when the AOA pilot team loaded the AOA part list into Q-Star™, it initially found about 70% of the AOA parts. After a few days, QTEC had updated their database to provide coverage of about 98% of the AOA list. This rapid recovery from fairly low initial coverage was impressive. This should improve with time since, when the number of parts in the database and the number of users increases, QTEC's coverage should increase. However, Q-Star™ responsiveness should be verified once its coverage becomes comparable with i2 or IHS. As the number of users and part numbers increase and the breadth of coverage improves, rapid addition of parts to the database may become less important but should still be confirmed to be adequate.

The QTEC tool provided occasional email alerts on changes in status of parts on the AOA pilot list. While the next tool version from i2, SRM, will also add this notification feature, CSM does not have this feature at this time. This was one of the most useful features noted by users and is already a part of several other tools including Total Parts Plus and Arrow's Ubiquidata.

8.5.6.4 <u>SiliconExpert</u>

SiliconExpert (http://www.siliconexpert.com) offers the largest parametric database of component data examined during the AOA Pilot. With over 50 million parts and growing, SiliconExpert is designed to provide the design engineer with a library of searchable technical data covering the world of production electronics. The SiliconExpert web site states:

The Electronics Parts Database is populated with orderable part numbers, Supplier names, Datasheets, Parametric data, Lifecycle status, PCNS and other Documents. Users can searched (sic), analyze, compare, cleanse and download easily the part information via the software tools. The content is normalized and standardized across suppliers using a common market classification system. The content can enrich legacy parts databases to bring them to current market status.

The automation of data collection implemented by SiliconExpert provides data for an annual cost of only about $1000 per named user, far less expensive than other tools with significantly less complete component information. Extensions of the tool are available that address component and supplier management, bill of material management and part searches. While lifecycle status data is less robust than some tools we reviewed, the AOA pilot found this tool to be a very cost effective addition to the component and obsolescence management process since its ability to find and correct orderable part numbers from partial or errant information was quite impressive.

In summary, late in the AOA Pilot we looked at a number of tools and compared them with at least subjectively with the CSM/LCM data from i2. Many of these tools have features and cost performance trades that would make them excellent additions to the obsolescence management tool kit for major aerospace companies. However, none of these tools appear to have accuracy and coverage adequate to make other tools unnecessary. Therefore, multiple sources of obsolescence data on electronic components must be used to prevent popup issues that require mitigation at increased cost (when compared with part purchases from their original source).

8.5.7 <u>Recommendations and Findings</u>

In this section we will compile the key business cases and findings of the study then provide recommended best practices. Table 8.25 provides a final tool comparison that shows the relative advantages and disadvantages for all of the tools reviewed.

Table 8.25 - Final Tool Comparison

							4D Online	Arrow Ubiquidata	Avnet Promiere	i2 LCM	i2 TACTRAC	IHS Prescience / CAPS Expert	QTEC Q-Star™	Silicon Expert	Total Parts Plus
	USABILITY	**Wgt**	**How Rated**	**Min**	**Nom**	**Goal**									
1	User Interface Usability	30	Factor 1 - 10, 1 = worst	5	8	10	8.0	8.0	8.0	6.0	8.0	10.0	10.0	7.0	10.0
2	Report Usability	20	Factor 1 - 10, 1 = worst	5	8	10	8.0	7.0	8.0	7.0	7.0	10.0	10.0	3.0	10.0
3	Administrative Usability	15	Factor 1 - 10, 1 = worst	5	8	10	9.0	9.0	9.0	6.0	6.0	6.0	9.0	9.0	9.0
4	Training/Complexity	15	Factor 1 - 10, 1 = worst	5	8	10	8.0	8.0	8.0	6.0	8.0	7.0	8.0	8.0	8.0
5	Change Alerts by Email	20	Factor 1 - 10, 1 = worst	5	8	10	7.0	10.0	7.0	3.0	5.0	7.0	10.0	3.0	10.0
	SubTotal	**15**					**8.0**	**8.4**	**8.0**	**5.6**	**6.9**	**8.4**	**9.6**	**5.9**	**9.6**
	PERFORMANCE														
1	Relative Part Coverage	25	Factor 1 - 10, 1 = worst	5	8	10	9.0	7.0	9.0	9.0	6.0	8.0	6.0	10.0	7.0

							4D Online	Arrow Ubiquidata	Avnet Promiere	i2 LCM	i2 TACTRAC	IHS Prescience / CAPS Expert	QTEC Q-Star™	Silicon Expert	Total Parts Plus
2	Relative Alternative Part Count	15	Factor 1 - 10, 1 = worst	5	8	10	6.0	6.0	6.0	6.0	8.0	8.0	8.0	8.0	10.0
3	Data Accuracy	50	Factor 1 - 10, 1 = worst	5	8	10	8.0	6.0	8.0	8.0	7.0	8.0	6.0	8.0	6.0
4	Processing Speed	10	Factor 1 - 10, 1 = worst	5	8	10	8.0	8.0	8.0	5.0	8.0	10.0	10.0	9.0	10.0
	SubTotal	**30**					**8.0**	**6.5**	**8.0**	**7.7**	**7.0**	**8.2**	**6.7**	**8.6**	**7.3**
	PROGRAMMATICS														
1	Tool/Developer Stability	40	Factor 1 - 10, 1 = worst	5	8	10	6.0	3.0	6.0	6.0	5.0	7.0	6.0	6.0	9.0
2	Environment/Administrative Support	35	Factor 1 - 10, 1 = worst	5	8	10	8.0	6.0	8.0	6.0	6.0	6.0	9.0	8.0	9.0
3	Sever Security	25	Factor 1 - 10, 1 = worst	5	8	10	5.0	5.0	5.0	10.0	8.0	10.0	9.0	5.0	5.0
	SubTotal	**15**					**6.5**	**4.6**	**6.5**	**7.0**	**6.1**	**7.4**	**7.8**	**6.5**	**8.0**
	SCHEDULE														
1	Tool Implementation Ease	30	Factor 1 - 10, 1 = worst	5	8	10	10.0	10.0	10.0	5.0	7.0	6.0	10.0	10.0	10.0
2	Production Time Savings	70	Factor 1 - 10, 1 = worst	5	8	10	8.0	8.0	8.0	8.0	7.0	8.0	5.0	6.0	8.0
	SubTotal	**15**					**8.6**	**8.6**	**8.6**	**7.1**	**7.0**	**7.4**	**6.5**	**7.2**	**8.6**
	OWNER-SHIP COST														
1	Low Initial Tool Cost	25	Factor 1 - 10, 1 = worst	5	8	10	8.0	6.0	8.0	5.0	6.0	5.0	9.0	9.0	8.0
2	Low Installation Cost	25	Factor 1 - 10, 1 = worst	5	8	10	10.0	10.0	10.0	5.0	7.0	5.0	7.0	10.0	8.0
3	Low Initial Training Time	15	Factor 1 - 10, 1 = worst	5	8	10	10.0	8.0	10.0	5.0	7.0	7.0	9.0	10.0	9.0

							4D Online	Arrow Ubiquidata	Avnet Promiere	i2 LCM	i2 TACTRAC	IHS Prescience / CAPS Expert	QTEC Q-Star™	Silicon Expert	Total Parts Plus
4	Recurring Maintenance & Training Cost	25	Factor 1 - 10, 1 = worst	5	8	10	8.0	7.0	8.0	5.0	7.0	6.0	10.0	10.0	8.0
5	Server, OS, and Environment Cost	10	Factor 1 - 10, 1 = worst	5	8	10	10.0	10.0	10.0	5.0	7.0	6.0	7.0	10.0	10.0
	SubTotal	**25**					**9.0**	**8.0**	**9.0**	**5.0**	**6.8**	**5.7**	**8.6**	**9.8**	**8.4**
	Overall Rating						8.1	7.1	8.1	6.5	6.8	7.3	7.7	7.9	8.2

8.5.8 Conclusion

Lockheed Martin Missiles and Fire Control - Dallas conducted the F/A-22 Automated Obsolescence Assessment (AOA) Pilot to explore the relative utility and validity of i2 Technology's Life Cycle Management (LCM) obsolescence data. During the AOA pilot, LMMFC-D personnel repeatedly queried our Component Supplier Management (CSM) system to analyze representative electronic component bills of material from F/A-22 subsystems. The study team then compared the CSM/LCM data on the representative components to obsolescence data from several of other data sources commonly in use by the F/A-22 and other Lockheed Martin programs. For example, the obsolescence database used historically by the F/A-22 was TacTech's TACTRAC database (acquired by i2 via their acquisition of Aspect Development after Aspect acquired TacTech). Some of our other programs depended on Arrow Ubiquidata, TacTech AIM/MAX and/or Total Parts Plus. These were among the other data sources the study team compared.

To varying degrees, the study team also explored the data of several emerging obsolescence data sources including (in alphanumeric order) 4D Online, Avnet Promiere, IHS/Precience, netCOMPONENTS, Part Miner, PCNalert, QTEC's Q-Star™ and SiliconExpert.

Variances in the tools could make one tool better than another for a particular situation and set of constraints. For example, all the tools the study team evaluated had adequate performance for new development programs but some, like those from Total Parts Plus, i2/TACTech and IHS/Promiere, had better historical component data that would be valuable for older production and sustainment phase programs. Some tools like i2's and SiliconExpert's had an extensive data base of component parametric data making them stronger candidates for engineering part-selection tasks or for obsolescence mitigation by selecting alternative parts. Part Miner, Promiere and Ubiquidata had information on current market volume conditions, distributor inventory and pricing data that would make them powerful tools for procurement and materials support. Other tools had the advantage of being in use by certain DoD customers. For example, the Army's obsolescence working group in Huntsville uses Total Parts Plus to monitor obsolescence on its programs like MLRS, TACMS, THADD and PAC-3. This makes Total Parts Plus the logical choice for Army programs while AVCOM is a better choice on many Air Force programs. Although it is a newcomer to the field, QTEC Q-Star™ system is now available to the entire DoD obsolescence community and is designed to facilitate collaboration across programs and services. Q-Star™ thus may eventually become the baseline tool of choice for most individual programs and enterprise obsolescence data needs.

Another consideration is technical data security and integration. Some tools offer higher levels of security and/or integration with company back-office processes. For example IHS/Prescience and i2/SRM are designed for deployment on private servers (behind company firewalls) that integrate with Enterprise Resource Planning (ERP) and Product Data Management (PDM) servers at the enterprise level. This architecture allows increased security compared to systems that operate from public servers over the Internet.

Thus the study team found that the selection of a tool is a complex process of matching performance, cost and features for each particular requirement. In summary, no one tool can be considered the "best" for all needs. Rather a tool mix seems to best meet complex needs for coverage, security, integration, collaboration, usability, and accuracy. In fact, the AOA study found that using only one source of data could result in increases in the cost of managing obsolescence while multiple data sources significantly improves the probability of identifying issues early enough to use solutions (like bridge buys) that are significantly less expensive that others (like aftermarket or emulation).

8.5.9 Cost / Benefit Analysis

Recurring component costs as estimated by DMEA are 5 to 10 times the baseline cost. Thus assuming an average baseline cost per part of $50, the typical program will spend and extra $200 to $450 per item if a part must be sourced from the aftermarket. This is likely a conservative assumption since for the four items on last time buy during the early phase of the program, approximate prices were $1.91, $38, $452 and $1230 (an average price over $430 rather than $50) for quantity 500. For a program to use the aftermarket on 10 missed DMS parts per year, a penalty cost of $20 to $45 million results. To summarize, a typical site's savings of just changing from a legacy TacTech system to a LCM Content Data approach would be:

i2's LCM data coverage (F/A-22's active electronic parts)	=	96%
TACTRAC coverage (before Content Data added)	=	76%

Note: The 20% difference identified 3 F/A-22 parts, one of which was discontinued (5962-9211601HZA), and two that were sole source parts with LTB dates issued (5962-8946801XC and AT17LV020-10JI)

Annual Program Savings (at 18 parts/year/program)	=	$126,000
Annual Site Savings (avg. 10 programs per site)	=	$1,260,000
Annual Data Management Labor Savings	=	$3,240,000

(120 parts/program X 27 hrs/part X 10 programs/site @ $100/hour)

In the case of the F/A-22 program, the savings were calculated to be $45M. If using an average of 2 such major integration programs per site, this equals a total savings of $90M per site. per obsolete part found. This is based on a $500 Part cost (aftermarket penalty) X 10 (20% of 50 parts/yr going obsolete) X 10,000 Qty. Applied across the entire Lockheed Martin Enterprise the savings increases to $450M per year, assuming 10 such programs across the company.

It is clear that the increase in magnitude of a major integration program such as F/A-22 can help the savings from eliminating a potential system-impacting change far outweighs the cost of the database, software, necessary data integration, and data management, training, and software maintenance manpower. These numbers can also be validated with the knowledge that the F/A-22 program paid Intel $22M to reopen their obsoleted i960 microprocessor line to provide additional parts for the F/A-22 system's common processor. Since every subcontractor was required to use the same processor, the problem was worked using the leverage of the entire program with a single solution.

Section 9

Conclusions, Recommendations, and Cost/Benefit Summary

The overall POMTT program has proven to be every valuable to the POMTT Team's members. As can be seen in the previous sections, the pilots were able to prove the viability, financially and in performance, of each tool evaluated. Even in those found to be not specifically applicable to the program, a related potential benefit was identified and adjustments were made (such as in the case of RADSS 2000 and LMC's ODT). Additional benefits such as new processes, new tools, and better education and awareness have been identified as well. The details are provided in the following sections.

Although the technology and production pilots were the primary vehicles, other research performed on related tools and technologies that were competitors to, or partners with, the pilot tools was important. Also valuable was the enhanced communication, open discussion, sharing of data, and teamworking facilitated by the OMST and EPI CTI Working Group.

9.1 <u>Lockheed Martin</u>

In addition to the previously mentioned benefits, additional databases and sources of data were identified, created, and purchased. Some were selected and obtained to help reduce risks (Qtec, i2 Content Data) and some were created to meet a need (Corporate Obsolescence Database, Components Engineering Obs. Database).

Other benefits included new processes and procedures (such as the Corporate Obsolescence Management and Parts Management Guidelines), greater visibility of the obsolescence issue and potential solutions through working directly with programs, disseminating and sharing the program-developed expertise, and being able to support project requests for solutions, techniques, and tools (the Hellfire Obsolescence IPT and Black Belt Project on Materials Metrics).

9.1.1 <u>Higher Level Obsolescence Solutions</u>

At the Lockheed Martin Joint Symposium 2001, President and COO Robert J. Stevens stressed the importance of teamwork across sites. He said that "technical excellence ...isn't going to be enough", and that it is“... our responsibility to set-up the kind of interface standards and process standards that will let us to move work around and align this corporation in a way that can take parts of all the companies that we represent, assemble them quickly and seamlessly, with uniform formatting for information flows...”. This requires integrated processes, cross-company data sharing, the identification of common design needs, Customer / Program Office Coordination, New Contract and advance schedule planning, multiple levels of integration, and technology management.

Individual programs, such as LANTIRN, have been leaders in managing component obsolescence issues. In the past however, Lockheed Martin did not generate the business cases necessary to convince programs that a continuous management program is needed and would reduce life cycle costs versus reacting to issues as they arise. Solutions (tools, practices, etc) need to be established at a much higher level than what usually occurs at the project level.

Missiles and Fire Control - Orlando has helped lead the development of Lockheed Martin's best practices and tools that address managing this issue and culminated in the release of two key corporate Engineering Process Improvement Guidelines (EPI BP).

The key to this process is the evaluation and deployment tools and techniques that continuously assess the "health" of the program and to develop an effective mitigation plan to that helps provide the lowest cost solution. A fundamental input to this monitoring is the maintenance of technology roadmaps for each discrete component technology and maintaining a close liaison with the supplier community to keep the roadmaps updated. Overall, the recommendations include:

- Within each program, a process should be defined for dealing with obsolescence. This can be something as simple as continuous reviews for small programs or a staffed obsolescence management team for a much larger system.
- Obsolescence mitigation should be established as a job-performance metric, especially for critical personnel such as engineers, logisticians, buyers and program managers, to reinforce the importance of mitigation.
- Design engineers should use open systems and modular system architectures to plan for obsolescence that is unavoidable.
- The military services need to ensure that there is adequate funding for obsolescence mitigation, for both legacy and new systems, for support activities and manpower, parts substitutions, re-qualifications, redesigns or last-time buys.
- Government and industry managers need to monitor component usage patterns and maintain close vendor relationships to maintain component availability for existing systems.
- Since technical data can be lost or become obsolete, it's essential to characterize and catalog component functionality for critical components approaching obsolescence.

9.1.2 Customer

Although the potential savings/costs to the Air Force or other Lockheed Martin customers will not be calculated nor included in this report (due to the limited knowledge of their systems, needs, and capabilities) it must be noted that savings incurred by an Original Equipment Manufacturer are typically passed on to their customers. These savings are often magnified by the customer's per/unit multiplier and quantity of purchased products. This is true of Lockheed Martin's products and is indicative of LMC's interest in continuously reducing costs.

9.2 Recommendations

Approaches that address obsolescence issues can generally be classified as Reactive and Proactive - which both have their value. Proactive approaches provide the greatest return through lower costs, greater number of decision options, and these should be put in place in the broadest manner possible to impact the greatest number of programs and sites. Unfortunately, most commonly used solutions are Reactive, even though it is well recognized that they should only be used as a last resort backup to a proactive approach.

9.2.1 Proactive Obsolescence Management

It is difficult to plan for diminishing sources, as one needs to predict which sources will exit the business. The technology roadmap process will give a good indication of which technologies in the design are at high risk (i.e. old technology, single-source). However, it is difficult beyond that point to predict when a component will go obsolete. A great deal of analysis and data collection is required to produce more fidelity in predicting obsolescence. An example of a Proactive plan is shown below:

PROACTIVE OBSOLESCENCE APPROACH

1. Capture Bills-Of-Materials, including subcontractors
2. Identify and group items by obsolescence sensitivity
3. Assess and continuously monitor parts based on their need
4. Establish upgrade/replacement plans for impacted parts nearing obsolescence date
5. Involve other funding sources/agencies where available (DMES, DLA, GEM, etc.)

LM-MFC experience has shown that the single most valuable technique is to form a close technical liaison with the supplier. Often, under this relationship, LM gains insight into the processes the vendor exercises to determine which products to obsolete. Having a few months warning can offer tremendous advantages to helping find the lowest cost solution. Fortunately, finding a Form, Fit, and Functional replacement has solved most obsolete parts issues. In rare instances, LM has had to repackage silicon and, although more costly, this has kept production lines up and running on the LANTIRN program for over 15 years.

9.2.2 Reactive Obsolescence Management

Unfortunately, LM does not do as good a job in planning for obsolescence as it should. Each program tends to work issues on a case-by-case basis. The LANTIRN program has been a leader in managing component obsolescence issues. In the past, LM did not generate the business cases necessary to convince programs that a continuous parts management program is needed and that it will reduce life cycle costs compared to reacting to issues as they arise.

For example: the F-15 Program experienced these problems prior to the mid-90's and set on a course to resolve one of the most nagging problems with avionics systems, "reactive" management of diminishing manufacturing sources (DMS) for semiconductor components. In a world that sees technological advances as routine, the semiconductor industry is constantly adopting new processes and technologies, while leaving older less profitable technologies by the wayside. The newer technologies support a broad spectrum of, primarily, consumer and industrial products such as, computers, telecommunications, Internet tools and others. These technologies, which have high volume requirements and potential for sustained growth, drive the market, while many of the older technologies, critical to sustainment of military systems, are waning in support. For the reasons mentioned above, semiconductor components were viewed as being one of the highest impact/risk electronic part types used in avionics assemblies. A critical need was evident for a method of successfully tracking and managing DMS for these components.

"Reactive" management of DMS issues on military systems is an ineffective and cost-prohibitive endeavor. The status of DMS issues must be determined quickly, in order to have maximum lead-time, for evaluation and implementation of solutions. What is needed is a near-instantaneous assessment and impact analysis. Existing systems such as a company procurement, engineering, or Manufacturing Resource Planning (MRP) system can provide obsolescence identification, but usually after the problem has already been identified. For example, e-mail systems are currently used at many companies to disseminate obsolescence notices, although not very efficiently. An email received during the project highlighted Symmetricom's intent to discontinue numerous part numbers as noted in the GIDEP DMSMS listing. Company procurement records were then used to identify which persons or program had requested items on Purchase Orders (Pos) that were supplied by Symmetricom. This info was provided was only provided as a courtesy to be worked as each recipient deemed appropriate. It is clear that is these cases, opportunities can be and are being lost when programs/persons fail to take action, even when notified before the Last Time Buy date has passed. An example reactive approach is included as follows:

REACTIVE OBSOLESCENCE APPROACH

1. Capture Bills-Of-Materials, including subcontractors
2. Identify obsolescence impacted parts
3. Use ODT tool to quickly identify the most viable solution
4. Put solution in place
5. Involve other funding sources/agencies where available (DMES, DLA, GEM, etc.)
6. Establish proactive plan for other parts nearing obsolescence date

9.2.3 Risk Mitigation Strategies

Risk mitigation of obsolescence requires constant obsolescence management on a program-by-program basis by a multi-functional team and that includes the customer. What works for one program will not always satisfy another so these solutions must be flexible and, in some cases, applicable as needed. Strategic supplier relationships and continuous or periodic reviews of all program parts with suppliers should be performed and look specifically at market longevity, sales volume, and what alternate technologies are also available.

Additionally, all tiers of the supply chain must have OM programs in place including system contractors, subcontractors, and piece part manufacturers. OM must be an integral part of the parts management process especially in the military system marketplace since they do not have the volume that drives and funds the changes typically seen in the commercial world.

In some instances a component level solution may not be the best solution. For example, some sites and programs are primarily system integrators that use very few individual components. These must be accommodated in their needs, and process flow-down is one solution that reduces the risk at the OEM by pushing the solution down to the point of need.

9.2.4 Other Obsolescence Management Issues

Certain obsolescence tools and approaches do not always work for all systems. For example: Missiles are built once and then stored for long periods. Companies and programs must begin to initially plan for more card real estate availability as component functionality increases and part size decreases over time. They must also plan for board layout changes or replacements.

Unfortunately, these plans are normally limited to only the expected/contracted life of the system. This is because authorized funding can only be used on the authorized programs and only for existing or future needs for that particular system or lot. Future purchases and spares are contracted separately and are funded as needs and funding becomes available.

Programs must begin to schedule multiple decision points and milestones to review continuous upgrades for obsolescence and technology insertion rather than just assuming a complete system or LRU redesign.

They must also expect a reduced level of reliability data and available testing for COTS parts. Manufacturers respond to the commercial marketplace and test scenarios and system lives are already short and getting shorter in this arena.

Programs must always be ready and have solutions available for unexpected obsolescence (i.e. From Green to Red, with no Yellow) even if they have a proactive process in place.

Open architecture design is another key to making designs more obsolescence tolerant. Techniques such as dual footprints for ICs and other techniques can result in dramatic LC cost savings.

Finally, there are different levels of assessment and integration that can be applied to the problem. Most current solutions are based on part types and used as needed but solutions can also be integrated through processes. For example, the use of mezzanine cards (daughter boards), design standardization/re-use, virtual design and test, planned technology refreshment, longer-term procurement contracts, part stocking, partnerships and key supplier relationships, customer/supplier/OEM teaming, and greater tool/system integration.

9.2.5 <u>Subsidized Support Programs/Agencies</u>

A number of free and low cost agencies and support programs have been created over the last 5 years that are now available to OEMS, subcontractors, and military services. The General Emulation of Microcircuits (GEM) program (managed by the Sarnoff Corp.), DMEA's Flexible Foundry for obsolete IC processes, and GIDEP's Diminishing Manufacturing Sources and Material Shortages (DMSMS) notices have been providing programs with source of components and information for electronics systems. These services are subsidized by U.S. government agencies (DSCC, DMEA, and the DLA) and can provide qualified parts, automated data search tools, a library of military standards and specifications, life-cycle maturity estimating tools, and reverse engineering, and obsolescence notices on piece parts, especially in the (microcircuits) electronics area.

These are especially important for older military programs, which often employ component technologies that have been abandoned by mainstream semiconductor manufacturers. Some of the projects included in this area are: the DMS Shared Data Warehouse, the DMSMS Prediction Tool, and the Army DMS Info System.

The Obsolescence Center Of Excellence (COE) is another growing resource, especially for all of the military services, and was established in 2002 to provide a single, multi-service agency to address obsolescence and facilitate GIDEP's transformation from document to knowledge management. By linking databases, suppliers, resources, manufacturers, and providing solutions they would become the government's (both federal and military) focal point for DMSMS information.

9.2.6 New Business Support

One of the key recommendations concerns the support of inputs for new proposals. Military customers are now including obsolescence management requirements into their requirements and these must be addressed. The simplest solution is to have an overall process in place that is supported with the latest tools and techniques that are continuously reviewed and improved. These will result in a continuous process, especially when incorporated into a complementary process management system like CMMI.

9.2.7 Best Practices and New Procedures

Obsolescence and Parts Management Guidelines have been established at a corporate level at Lockheed Martin. Created through participation in Lockheed Martin's EPI Center, these provide a suite of recommendations, best practices, and solutions that can be used at any Lockheed martin site and tailored to fit. In addition, education has been provided through application and support training for the tool evaluations, as well as through the multiple presentations, conferences, technical interchange meetings, and corporate and program telecoms and support.

Additionally, a Lexicon was created at the beginning of the program to bring all parties together with a listing of terms and definitions agreeable by all sites. Finally, a Tools Evaluation Database was created as a repository for the POMTT evaluations to make them available across the corporation. Although the pilots were still completing, the database has already been used to capture almost 50 other evaluations on software tools from around the company.

9.2.8 Final Needs

Two critical areas of obsolescence management highlighted by the POMTT program are in the area of subcontractor parts control and solution funding.

9.2.8.1 Subcontractors

One critical area of obsolescence management highlighted by the POMTT program is in the area of subcontractor parts control. The recognized need is to either flow down obsolescence management requirements to a subcontractor, or require them to provide their parts so they can be managed by the prime. Several issues must be resolved, and may exist in different combinations, depending of the size, technical capabilities, and trust existing at the sub and prime.

Subcontractors have to overcome their fear of losing design control by providing key technical component or schematic details to their prime. This requires considerable trust (or a legal recourse) as well as a contractual requirement. If they don't provide their own parts, then they must have the technical expertise and tools to predict, monitor, and solve obsolescence events when they occur. The expertise and cost of tools are beyond the abilities of many smaller subcontractors.

Regardless of which solution is required or selected, several actions can be undertaken to put the solutions into place. Language must be provided in the subcontract to flow down the obsolescence management requirements imposed by the customer and allow the contracting parties to establish a mutually agreeable approach.

The approach can be of limited involvement, i.e. it may only need to include the most obsolescence sensitive items such as IC's, black boxes, and vendor-identified items only.

Finally, it should protect proprietary information by limiting the amount and type of data provided. There should be not drawing or assembly usage identification other than textual references (Video card Assy., CCA # 1, etc.). Enough data should be provided to allow accurate identification of the items without providing so much detail that it reduces the subcontractor's ability to sell their products.

9.2.8.2 Solution Funding

The next need is to develop a method to get programs, companies, and customers to fund obsolete part solutions when notified. Many opportunities to purchase components at existing prices during the Last-Time-Buy (LTB) period are passed by because of a lack of decision, a lack of funding, and a lack of recognition.

In one example, a Lockheed Martin program was notified of an impending obsolescence by the manufacturer. The application required a Cypress part in a military temperature range and LCC package. The program personnel were notified at that time of what needed to be done to take care of the issue, however no action was taken. In this case, the program had almost 12 months to make their decision and procure the needed parts.

The part continued to be available in a PLCC (Plastic Leadless Chip Carrier), J-lead configuration that had a much higher profile height and a lower temp range capability. The parts were closed in the engineering database to prevent future selection and usage and removed from the active MENTOR Symbol library.

In another example multiple requests for funding to obtain available parts were ignored until the problem became much worse. In this case there was a request sent in March, 2001 to address the need for immediate funding for a Xilinx XCR22LV10-15PC28I in response to a LTB notice.

The P3X22V10IBA is a 3.3Vdc fuse link PAL in a 28 PLCC package that was produced by Philips. Xilinx purchased the line from Philips and later chose to discontinue the line. It was to be offered in the future only in larger die and pin count devices. The result was that there would be no pin replaceable parts available for future procurement. 53 pieces were on order, but an actual quantity of 125 pieces (min) was needed to complete the remainder of the existing lot build and any replacement parts needed for existing CCAs that may have failures or new code requirements. Since the LTB date was in late April, something needed to be done soon. A change request was prepared but the program had to act fast on the MR for the new device. The manufacturer's representative stated that it should be no problem to get the necessary parts and that the parts cost less than $3 each.

Obviously, just because a solution is proffered and not acted on it does not always mean that the solution was ignored. Often times there are additional issues that are being considered such as future production plans, comparing continued production, and contracts for future lots as opposed to developing and selling potential upgrades. Component based solutions must be compared and contrasted with assembly based options since, sometimes, the costs are similar and there is another payback in the form of reduced weight, reduced complexity, increased reliability, and better performance. However, there needs to be a process for notification, and action that is closed loop so component and design engineers are notified that a decision was made, even if it was not the one provided.

9.3 Cost/Benefit Summary

The following sections summarize and total the savings and cost avoidances from each of the Technology and Production pilots, as well estimate savings from non-quantified sources such as training, communication, etc.

Three types of cost benefits are used in the following sections: Cost Avoidance, Cost Reductions, and Cost Savings. For the purpose of this document these are defined as follows:

> **Cost Avoidance** - savings associated with *deferring or eliminating pre-planned expenditures*, sometimes resulting in some diminishment of service.
>
> **Cost Reductions** - savings *associated with an established "baseline"* of spending for a particular service.
>
> **Cost Savings** - the sum of both Cost Avoidance's and Cost Reductions, net of investment and other life cycle costs.

For each pilot, these may be identified separately (if known) or combined to provide a single cost/benefit value.

Some cost values used in this section were calculated using the Cost of Obsolescence study performed by Lockheed Martin Missiles and Fire Control – Orlando (October 2002). Others use values generated from DMEA's Resolution Cost Metrics for Diminishing Manufacturing Sources and Material Shortages study (December, 2001) (Figure 9.1). In some cases, it was not possible to accurately calculate the actual cost values due to a lack of detail on the costs or tasks, or simply because there was not enough time or funding available to identify all the many data sources, capture the data, and validate it.

Cost Avoidance Values
(Then Year 2002)

Resolution Type		Cost Avoidance Calculation (Average)	
		NRE	Cost Avoidance
Existing Stock			$ 7,000
Alternate		$ 7,000	12,000
Substitute		19,000	31,000
Aftermarket		50,000	22,000
Emulation		72,000	45,000
Redesign	Minor	117,000	316,000
	Major	433,000	0
LOT or Bridge Buy*		N/A	N/A
Reclamation**		2,000	N/A

* LOT or Bridge Buy cost is program specific

** Reclamation is not recommended for microelectronics

Figure 9.1 – DMEA Cost Avoidance Values

Therefore, the two studies were used to get an accurate picture of costs at Lockheed Martin and throughout the industry (DMEA).

Additionally, since the Technology pilots were less intensive and focused more on downselecting tools for potential pilots, there was not as detailed a cost analysis provided as on the Production pilots. However, cost assessments were made for each and are included as follows, and in the final summary.

9.3.1 Technology Pilots

The savings and cost avoidances from the five technology pilots (VP Technologies / Longbow Pilot, Boeing SSED / Hellfire ASIC, MOCA / MTADS, MOCA / ICE, RADSS / PRADA) are summarized in the following sections.

9.3.2 VP Technologies / Longbow Pilot

Comparing VP Technologies with Lockheed Martin's in-house practices, and other commercial remanufacturers, did show a cost and timesavings, as well as higher costs and longer times. When comparing VP's performance to *Lockheed Martin's* existing capabilities:

- VP Technologies produced a 39 percent timesavings and a 15 percent reduction in cost over LMC's in-house practice of manually transferring a legacy design.

- Although VP's and Lockheed Martin's development costs are about the same, VP's the time to availability of the new design was 37 percent less.

When comparing VP Technologies to a *commercial remanufacturer* the costs were again favorable, with some exceptions.

- The total cost was almost identical between the VP and *one* outside competitor.
- VP Technologies did not fair as well in cost against the majority of the commercial remanufacturing industry. VP's design cost was typically 27 percent higher, even though they did not include the cost of sample parts.
- VP Technologies' approach reduced the component redesign time by 16 percent.
- In total though, VP's time to market VP was 24 percent longer.

It is important to understand that the numbers can be confusing when comparing costs and times. Both Lockheed Martin's and VP's models are technology independent, whereas models developed in the commercial marketplace are developed with a specific technology in mind that will be used to produce the part.

Each of the pilot evaluation cost estimates included slightly differing elements making them difficult to compare. For example: Lockheed's model includes place and route, simulation, and extracted timing while one industrial manufacturer included ten prototypes in his cost. The comparison between dependent models, however, is a true comparison although, there are details to be made aware of. For example: VP Technologies included a one-time charge of $22,000 for development software in their total cost. Without this charge, or if the cost had been amortized over a number of customers, the savings would have been even greater with a 7 percent reduction over the commercial company's cost, and a 20 percent savings over Lockheed Martin's.

There is also an unknown cost associated with the risk of using a small, non-established company like VP. They do not have the capital funding or customer base to be able to spread the cost of software over many customers. They also do not have the funding resources to quote a lowered cost at startup, and recoup the costs through an extended production run. Finally, their potential risk is much greater since they are primarily led in technology by one key person (Dr. Madisetti) who is also the owner, and the company would probably dissolve if he was not involved.

Since, in this case, Lockheed Martin chose to take this relatively more simple design and have it bid by non-Lockheed Martin sources, the cost benefit analysis also focused on those suppliers.

VP Technologies' greatest benefit was with their PHM capability which allowed for increased productivity by automating the translation and testing of the legacy code. The translated code was correct by virtual design, testing, and construction and resulted in zero errors. This cannot be said of existing manual translation processes. In this example, it was proven that the proposed methodology and technology has the potential of speeding up the redesign and retargeting of a legacy designs by a factor of 3-5 over current approaches.

At worse case, there was an $11K savings in using VP Technologies on a single project. Assuming an average of 10 projects a year, this would result in a total of $110K per year for one site alone. Even the smallest savings are significant when magnified by the scope of the problem.

9.3.1.2 Boeing / Hellfire Pilot

Boeing was not able to fully exercise the Orora toolset on this pilot due to time constraints. However, the pilot did identify two possible foundries and candidate processes for translation of the Hellfire Pre-Amp design. The Hellfire study also revealed there were no dielectrically isolated bipolar process capable foundries in the Flexible Foundry program. As a result, Boeing approached DMEA about having Legerity evaluated as a possible addition the flexible foundry.

The cost to produce a fabrication run using either Intersil or Legerity would result in differing quantities of untested die and different costs for subsequent orders. Extra die testing and packaging costs (not estimated) would also be incurred for both. There was also an option to run a split or multi-project run to provide preliminary die for verification testing. The redesign and production for each is expected to take anywhere from 11 to 17 months (towards 17 months if multiple passes are needed).

Risks include areas of concern for both foundries. Intersil's EBFH process has an apparent oscillation in one transistor circuit of the design. This oscillation could be a modeling issue with Intersil's simulator, as others have occurred in the past. If, after further testing, the oscillation continues the design will have to be moved to a different process. Legerity was the preferred foundry from a technical and cost standpoint, but all of their foundry work is performed outside the United States and poses a potential ITAR issue.

Lockheed Martin has some of the same design tools, experience, and capabilities in ASIC design and retargeting as Boeing, but not as much in mixed-signal devices. The differences in time, labor, and necessary toolsets are the factors that go into the cost/benefit analysis for this pilot. The total cost for Boeing's analysis to retarget the ASIC was $52K. If Lockheed Martin had to perform the same analysis it is estimated that the cost would have been about the same therefore, there were no cost savings assumed for this pilot.

9.3.1.3 MTADS / MOCA Pilot

The MOCA tool has a potential long-term benefit to Lockheed Martin due to its cost, availability, and potential performance. Applying MOCA when developing production schedules (through determination of the cost associated with each obsolescence solution choice) is very valuable since almost all programs are funded on a lot-by-lot basis, and planning for future, unfunded procurements that will be impacted by as-yet unseen obsolescence, is very risky.

It can help Lockheed determine when it would be advantageous to use company overhead funding, DLA requested stocking, or a separate customer contract to prepare for future production needs. This can eliminate delays in the original production schedule, hardware re-qualification, and or even complete redesign costs.

The cost of this tool is minimal due to the fact that Lockheed Martin is a member of the CALCE Consortium and has free access to the tool. Training has been provided for $1K and setup and use of the tools is relatively low since most of the cost is Non-Recurring and related to the model creation. MOCA is only available through CALCE consortium membership or some type of planned "research activity." $10K is about the minimum cost for a user's license and MOCA access for a specified period in the contract. This was the case for the pilot since Missiles and Fire Control – Orlando did not have a specific CALCE membership.

The team gathered data and provided it to CALCE but the program's negotiations on a follow-on contract did not allow use of the actual cost data. Catalog and published costs were used and the results that the Lockheed Martin cost was approximately 40 hours total. At a $100/rate this would equal approximately $4K.

There are potential costs that would have been incurred by the program if they had not performed the MOCA analysis. One of these includes the cost of unexpected and continuous obsolescence (since the program was designed in the 1970's and built in the mid-1980s). The lifecycle analysis of the video processor card revealed that (on an 81% match), out of 35 parts total, 33 parts (94%) were experiencing a reduction in sources of supply and had the potential of becoming obsolete at any time, 1 had been identified by its remaining manufacturer that it was being discontinued, and 5 had already become obsolete. If each of the obsolete parts had been replaced with a F^3I replacement (if available), applying the $7K DMEA cost avoidance factor would have resulted in a $35K cost avoidance. However, due to the number of parts in danger of imminent obsolescence, the MOCA tool recommended that the most cost effective time to plan a single major redesign for the card was in approximately two years – just before a large group of parts go obsolete. If any of these parts become obsolete before this date they will have significant impact on schedule and cost. Also, because of the build schedules the uncertainties insert significant economic risk into the solution for MTADS. Assuming the program can put into place a LOT program-stocking parts for the remaining life of the fielded systems, the cost avoidance would be the cost of the card redesign minus the cost of the parts and stocking.

The program decided to address the redesign of the card as part of the modernization program and will incur the redesign cost, but will also have the performance enhancement and increase in part availability due to the use of newer, emerging technology components.

Therefore, the total cost savings/avoidances for the MTADS video processor card were $35K, based on the program taking the simplest, lowest cost solution.

9.3.1.4 ICE / MOCA Pilot

This pilot analyzed the potential for integrating the PASES and MOCA tools together. Linking with ICE, MOCA would have access to embedded links ICE has to Price products. ICE would also allow MOCA to have access to manually input external costs (such as training, refresh, etc.). Unfortunately, MOCA assumes that there are no failures, that regular maintenance is performed during operating periods, and that no Operations and Support (O&S) data is included. It also assumes a 1-to-1 replacement scenario and does not take into account improvements from technology and new system capabilities. It is not designed to handle system retrofits. These are major factors that must be included as part of any assessment.

ICE only uses AFTOC data and does no verification to determine whether that data is accurate. ICE also only has historical data and is primarily parts oriented. It does not address cost issues related to technologies.

Since the project was an analysis of the potential integration there were no cost values assigned to this analysis.

9.3.1.5 PRADA RADSS for PCB Manufacturing Pilot

The RADSS 2000 tool was only analyzed over a two-month period and, although originally planned to be used on a daily basis, their schedule did not allow continued support by the Printed Circuit Board (PCB) manufacturing engineers.

After iterations of decisions model were created and problems and scenarios were set up, the following results were compiled:

- RADSS has the ability to compile large amounts of data and help make decisions
- The concept is simple and easy to understand
- RADSS must have Access '97 database available
- The Graphical User Interface (GUI) is not user friendly
- Entering and importing data is difficult and not suitable for everyday use
- The tool cannot handle multiple decision models and scenarios
- The price for a single license ($25K is too high
- The source code is not open for customizations or improvements
- Does not interface with other tools such as Excel or other versions of Access

Based on the data provided, it was determined that RADSS was not the appropriate tool for PCB manufacturing decisions. The concepts used in RADSS such as Resources, Cost, and Benefits don't relate well to values selected by the team (employee experience, machine deterioration, machine malfunction, etc.) so the benefit was estimated at approximately $3K per year.

9.3.2 Production Pilots

The savings and cost avoidances from the five production pilots are summarized in the following sections (i2 Technologies / JASSM, RADSS / LANTIRN, GT BGA / BAE FADEC, EDAptive / SLTA, i2 Technologies / AOA).

9.3.2.1 i2 Technologies' Life Cycle Manager / JASSM

The JASSM Pilot program applied the Cost as an Independent Variable (CAIV) approach using Dynamic Insight. The trade space included three alternatives: i2 Data without LCM, i2 Data with LCM and Predicted i2 Data with LCM. Although i2 Content Data is currently available at M&FC without LCM, it was later determined that the LCM/Content Data combination was the preferred method for use by LMMFC. The analysis determined that the best performance was with the LCM. Again it must be reminded that the analysis did not include savings from solving obsolescence events, only from identifying the best solution at the earliest stage possible.

Except for installation cost, the nonrecurring costs are amortized over a five-year period and included both Orlando and Dallas sites. The analysis assumes that there are around 50 to 300 configurations analyzed per year which equates to 750 to 1500 BOM's over 5 years and a maximum savings of $721K per year.

It must also be recognized that the savings from data management that, although not specifically captured, can be estimated using the obsolescence cost study data. As a program moves from an emergency (high cost) to a managed obsolescence process (lower cost), there is a resulting decrease in labor (see Table 9.1 below). It is also logical to expect that, as designers determine that they can obtain obsolescence data real time, especially on new commercial parts, that the number of evaluations will go up. As the life cycle status of every component is monitored on a regular basis and predictive analysis drives plans for technology insertion and refreshment, component obsolescence should also be reduced to only a few parts that become obsolete due to unexpected events. This eliminates inflated component costs, replacement analysis labor, additional simulation and testing, as well as complete assembly or LRU redesign efforts. All of these will result in a decrease of labor over the current manually intensive process. The cost of this reduced labor can be estimated using the values from the obsolescence cost study.

Table 9.1 – Labor Savings Cost Analysis

	EMERGENCY MANAGEMENT APPROACH	**MANAGED OBSOLESCENCE APPROACH**	**SAVINGS** (per program / per year)
LABOR COSTS	$ 321,210 [1]	$ 116,530 [2]	**$ 204,680**

[1] 74.7 hours/per issue x 43 (avg) events per year
[2] 27.1 hours per issue x 43 (avg) events per year

When these savings are added to the calculated savings per site ($721K), at an average of 10 programs per site, the total calculated savings becomes $2,767,800 ($2,046,800 + $721,000). There are also unknown savings from part number normalization across multiple sites through a common process that results in verified part numbers and reduces data entry errors. It can also simplify the processes following data selection such as checking, procurement, receiving and quality.

The risks associated with this type of obsolescence analysis must be understood. Although technological risks can be reduced from previous experience with i2's products and from training and experience, the risk of i2's proprietary algorithm is significant since there is no reported prediction accuracy. It can be reduced from continual monitoring and tracking, and from the use of an alternate prediction tool to verify/support predictions. Business risks are also an issue with this pilot since i2 has had serious financial difficulties but has reduced their costs and returned to their original management focus on their existing customer base.

Finally, although the cost payback point is relatively low for a tool of this size; it cannot be incurred except by a major program. Therefore, a single program would have to share the expense of such a tool with other programs across a site or company.

9.3.2.2 RADSS 2000 / ODT LANTIRN Pilot

The cost of developing and testing a RADSS model was calculated to be $27K for a single problem (not including the cost of the software). This model would typically not be applicable to another problem and since the non-recurring costs are the major funds expended here, it cannot be amortized across other obsolescence problems. If, however, the model is applicable to a new problem, the cost of using RADSS to tackle the new decision problem is approximately $25K. If a model already exists that could be applied to another decision, the resources required would only consist of manpower for data input and management at a cost of $6,000. However, this would require approximately 1.5 weeks of manpower would be too long to reply to an obsolescence issue.

This approach requires the purchase of the RADSS software ($25K) and significant training for a SME to develop the model and use the tool ($10K).

The use of the Obsolescence Decision tool with the RADSS tool results in a significant savings. The values provided in Section 8 (Figure 8.25–Savings Estimates) can be used to calculate the cost savings from the increase in solution speed resulting from the personnel's use of the tool. As users become more familiar with the solution process, experience increases resulting in a reduced amount of time to achieve a solution. In the simplest solution alternative (Verification and Replacement Identification) a reduction in hours from a novice engineer (39 hours) to those required by an obsolescence SME (26 hours) results in a 33% increase in productivity and approximately $1.3K savings per decision (13 hours X $100/hr rate). When this is multiplied by a program average of 54 obsolescence events (for those that actively manage obsolescence) it results in a savings of $70,200 per program.

Obsolescence decision analysis must be done quickly and 80 to 90% of most solutions are simple replacements with relatively small amount of data and variables. Redesigns or component reengineering will take longer and cost much more, but are where the benefits of RADSS really come into play. The combination of both ODT and the RADSS tool provides the best obsolescence decision support process and is unique in industry.

9.3.2.3 Georgia Tech / PEMS for Common Modules Pilot

Probably the most important finding in this study was that not all plastic ball grid arrays are created equal. PBGAs have a wide range of variation in material and internal construction features and, as die sizes increase, the overall package CTE will decrease. The primary difficulty occurs when PBGAs with a broad range of CTEs are used on a common assembly. It may no longer be possible to choose a board, module, or substrate material with a CTE that allows all the parts have an acceptable solder joint life.

The primary area of cost savings observed by a system or board designer and manufacturer is through reduced part or board qualification testing costs. It is estimated that BAE would save:

- Approximately $80k per package type (@ 5 pkgs per year = $400K)
- 5% fewer troubleshooting events
- 20% fewer repairs (approximately $40k per year)
- 70% reduction in the time to insertion of new technology (approximately 5 months faster per program)
- Capture of early reliability board level information on various suppliers' components
- A reduced risk of early wear-out failures
- Improved soldering parameters for improved reliability
- Greater confidence in the interconnect integrity during system troubleshooting.

Figure 9.2 shows DMEA's special testing costs and these have a good correlation with the BAE qualification costs for new PEMs. Here a reduction in the amount of time to qualify constitutes a significant savings. The pilot also showed a strong correlation between Georgia Tech's models and BAE's temperature cycling tests and proves that computer modeling is valid for predicting potential solder life issues. New procedures are in development and have been enacted at BAE that now uses the combination of computer modeling by Georgia Tech with actual temp cycling to complete the qualification process in less than <u>half</u> the normal amount of time (for selected parts).

Special Testing Costs

(Then Year 2002 Rounded to Nearest Thousand)

➢Type of Special Testing	➢Estimated Cost Range
➢New Source Qualification	➢$21,000 –$170,000
➢Radiation Hardening	
➢Dose Rate	➢$16,000 – $21,000
➢Total Dose	➢$5,000 – $13,000
➢Single Event Upset	➢$16,000 – $53,000
➢Plastic-Encapsulated Microcircuits	
➢Acoustic Microscopy	➢$650
➢Full Qualification (100➢pcs)	➢$50,000

Figure 9.2 – DMEA Special Testing Values

9.3.2.4 <u>TACMS / SLTA Pilot</u>

The SLTA Pilot Project was a valuable experience which could result in significant savings for future designs. The following cost/benefits analysis though, does not include initial development test savings or early fault isolation due to affordable testing at a lower level that avoids higher cost events (misdiagnosis of design issues, retest and additional redesigns). It also does not include potential savings from risk reduction, internal (interface) visibility, or faster change management.

A Missiles and Fire Control - Dallas baseline design approach is estimated to cost:

Create a typical circuit card assembly (design & test) = $300K

The cost of a typical number of design changes and iterations must also be estimated and costed.

Cost of 5 design iterations/yr/program = $1.5M

(Using a programs avg. of ~100 cards and 5% of those need redesign each year)

Using this same estimation method, System Level Design Approach Costs can be estimated to be as follows:

Software License Cost (2002 Pricelist) = **$25K**
(One-year term w/40 hours telephone & email support)

Rosetta Training Cost (not including travel) = **$6K**
(Materials, 1-day tutorial/workshop, test-case, one day of follow-up)

VHDL Code & Test Vectors creation labor (per board) = **$150K**
(1 design engineer X 1000 hours X $100/hour) + (50K test and evaluation)

Total SLDL Board Development Cost (per board) = **$231K**

Cost of 5 design iterations/yr/program = **$536K**
(1st design = $231,000, 2nd thru 5th = $304,920 (66% savings per iteration)

Based on this analysis, the savings at five design iterations/yr/program would be:

Savings (per program) = **$964K**

9.3.2.5 F/A-22 / i2 LCM Pilot

This pilot applied i2's LifeCycle Management Content Data to F/A-22's bill of material. It identified three parts that would not have been flagged as obsolete by the program's existing toolset. There was a 20% increase in part coverage in using the LCM Content data. Only 76% of F/A-22s parts were matched by TACTRAC (before the LCM Content Data was added) while the Electronics Database (ED) matched 96%. This 20% difference included three F/A-22 parts: one which was discontinued, and two that were sole sourced parts with LTB dates already issued.

Since recurring component costs as estimated by DMEA are 5 to 10 times the baseline cost, (at an estimated $50 cost per part) the typical program will spend an extra $200 to $450 per item if an obsolete part must be procured from an aftermarket source. This is a conservative value since, for four items on last time buy during the early phase of the program; approximate prices were $1.91, $38, $452, and $1,230 which resulted in an average price of over $430. For a major integration program of F/A-22s magnitude to use an aftermarket supply on ten missed DMS parts per year, a worst-case penalty cost of $45 million results.

It must be noted that the accuracy of i2s predictions must still be verified through a long-term evaluation. However, the accuracy of an obsolescence prediction only becomes a concern after the part is matched to the database. Therefore, a tool must first provide the greatest part coverage, and then an obsolescence prediction value, and finally an accurate prediction, in this order of precedence.

It is clear that the increase in magnitude of a major integration program such as F/A-22 far outweighs the cost of the database, software, necessary data integration, and data management, training, and software maintenance manpower. The savings values can be further validated with the knowledge that the F/A-22 program actually paid Intel

$22M to reopen their obsoleted i960 microprocessor line to provide additional parts for F/A-22's common processor. Since every subcontractor was required to use the same processor, the problem was worked using the leverage of the entire program with a single solution.

9.3.3 Savings from Non-Pilot Tool Evaluations

There were also benefits that were not actually associated with or part of the pilot evaluations that provided an uncalculated benefit to the company. Some of these were:

For example: participation in the EPI CTI-PG was an integral part of the project as the program changed focus from the OMST focus to the EPI focus. As part of this effort, there was development and education on other company efforts such as the establishment of a corporate obsolescence database, training in Technology Roadmapping and its application, sharing of data and presentations from Quarterly POMTT meetings, conferences, workshops, and reviews of industry activities and procedures.

Additional benefits were provided by program activities that were started from, or influenced by the POMTT pilot activities. For example: Orlando's Hellfire Missile program had been relying on customer management of obsolescence. But in early 2003 the program created a Parts Obsolescence Integrated Process Team to manage, not only events that were becoming more numerous as the system aged, but also to establish a mitigation approach for future contracts and production. The IPT met with and received support from POMTT personnel through consultation, tool training, and recommended approaches.

The Astronautics divisions Marietta facility became interested in obsolescence management as an integrator of multiple electronics systems for their products.

Other benefits were provided to the industry as well. NASA became interested in the work being done

9.3.4 Savings from Best Practices and New Procedures

Obsolescence and Parts Management Guidelines have been established at a corporate level at Lockheed Martin. Created through participation in Lockheed Martin's EPI Center, these provide a suite of recommendations, best practices, and solutions that can be used at any Lockheed martin site and tailored to fit. In addition, education has been provided through application and support training for the tool evaluations, as well as through the multiple presentations, conferences, technical interchange meetings, and corporate and program telecoms and support.

Additionally, a Lexicon was created at the beginning of the program to bring all parties together with a listing of terms and definitions agreeable by all sites. Finally, a Tools Evaluation Database was created as a repository for the POMTT evaluations to make them available across the corporation. Although the pilots were still completing, the database has already been used to capture almost 50 other evaluations on software tools from around the company.

9.3.5 Total Lockheed Martin Savings from POMTT

As can be seen from the above sections, all benefits cannot be quantified to provide a total cost savings/avoidance value. However, those savings and avoidances that were identified and captured can be totaled as follows:

Table 9.2 – POMTT Cost Summary

TOOL	PILOT	COST SAVINGS & AVOIDANCES (per pilot / per program) (in thousands)	NUMBER OF USING PROGRAMS (Est. Per Site)	COST SAVINGS & AVOIDANCES (Per Site) (in thousands)
VP Technologies	Longbow Missile	$11	5	$55
Boeing SSED	Hellfire ASIC [1]	$0	5	$0
MOCA	MTADS	$35	10	$350
	ICE [1]	$0	0	$0
RADSS / ODT	PRADA	$3	1	$3
	LANTIRN/IRST	$70	20	$1,400
i2 Technologies	JASSM	$277	20	$5,540
	AOA / F-22	$45,000	2	$90,000
GT BGA	BAE FADEC	$1,800	1	$1,800
EDAptive	SLTA	$964	10	$9,640
TOTALS		**$48,754**	**-**	**$108,788**

The table includes the cost savings and avoidances (per program) and applies an estimated number of programs per site that would be expected to use the tool as a multiplier to calculate the total savings per site. For example, some tools/technologies are more applicable to programs that are more mature such as one that provides a solution for parts already obsolete. Others are more proactive in their approach but have a much higher cost that must be amortized across a larger number of users. When totaled, this results in a calculated savings and avoidances of over $108 million per site.

Again, the savings/avoidances are a combination of actual and projected costs and do not include many other savings from enhanced testing, improved material handling, or improved manufacturability. Additionally, the increased use and integration of COTS technologies, the use of new corporate Obsolescence Management and Component Management procedures, the new corporate Tools Evaluation Database, the new corporate Lexicon of Terms and Definitions, and corporate teaming and education also provide unmeasured benefits.

The following table summarizes each of the tools, its solution approach, and how it can best be applied.

Table 9.3 – Company / EPOI Tool Comparison Summary

TOOL/TECHNOLOGY		LMC / BAE METHODOLOGY	EPOI SOLUTION	INTANGIBLES
i2 LCM / SRM		Manual Obsolescence Monitoring	Automatic DMS Evaluation	Better part number standardization
		Manual part searches	Parametric part searches	
		Limited teaming & data sharing	Common process/tool	
		Manual Maintenance	Integrated workflows & database utilities	
RADSS 2000		No common decision process	Decision support for major redesigns only	Not applicable for PCB Manufacturing
				Integration with SRM
				Common process
DVTG (VectorGen)		Manual test vector generation	Automatic test vector generation	
VP Technologies		Modeled in-house	Technology independent models	20 days faster
GT Reliability Prediction		Values estimated based on available data	Improved prediction based on material physics	5% fewer trouble-shooting events
				70% reduction in technology insertion time (5 months per program)
				50% reduction in qualification time
Mixed-Signal ASIC Design		Modeled discretely in-house	Faster, more accurate designs, additional source options	Foundry needed for dielectrically isolated bipolar process
MOCA		No obsolescence costs included in proposals	Obsolescence as an integral part of cost analysis	Longer program Sustainment
				Integration completed
				Better cost analysis

To summarize, the POMTT program exceeded the contract pilot performance requirements by 66% by completing 10 (6 required) Pilots and work is continuing. New proposals, the EPI / CTI-Working Group's corporate efforts, ongoing program and mission area implementation are all leveraging the investment made by the Air Force Research Labs and the POMTT Team members. The costs and cost sharing was all completed on schedule and within budget.

Of particular note, the SRM 6.0 Pilot identified 9 obsolete JASSM components, the BGA Physics of Failure pilot was used to help validate BAE's JSF design, and a Hellfire ASIC was retargeted to 2 potential new technologies. On F/A-22, the i2 LCM data identified 3 obsolete parts on the F/A-22 program, significant training and education was received using Rosetta, and many papers and presentations were made at internal IRAD Reviews and National and International Conferences & Workshop.

Section 10

Business and Financial Summary

The program was started in September 1999 and, by December, a budget re-spread was worked to match Lockheed Martin's current year (January to December) spend plan with AFRL' s fiscal year (October to September) funding profile. Inputs began being received from the IWTAs (LM Dallas, Baltimore, and BAE Control Systems) as they began to get started.

In the first quarter of 2000 the budget reallocation was submitted in current year (January to December) format to cover the 58-month contract period of performance. Program spending was initially running 10-20% less than planned, primarily due to the slower than expected ramp up of technical staff, and the holidays. By the second quarter of 2000, the underrun had declined. Manpower was by then set at the required level for the program as personnel were interviewed and hired for program positions.

Early on, it was noticed that differences in spending reporting periods resulted in lags in costs being identified. For example: Dallas reporting lagged behind all other IWTAs by one month so it was determined that their costs would be reflected in the following quarterly report.

In the third quarter of 2000, AFRL reported that LM was 33% under spent for Fiscal Year (FY) 2000. An investigation was then launched and determined that M&FC-Dallas invoices for the months of June and July had not been processed through Orlando's internal billing system and that these had reduced the actual invoices by approximately $25K. The remainder of the discrepancy is due to the difference in the calendar year financial reporting and the government's fiscal year plan. To alleviate the difference, it was agreed to shift $200K of year 2001 funds from FY01 to FY03. The resulting reserve would help protect the program from unplanned rate and factor changes, and facilitate the completion of tasks that could be delayed if tool development lagged.

In early 2001 spending was on schedule but differences were observed between what was being invoiced and how it did not match the program budget plan. This was investigated and found to be the result of several factors:

- Expending the remainder of 2000 IRAD funds
- Differences in the billing systems and cycles
- End of the year IWTA plant shutdowns
- December 2000 IWTA holdbacks due to potential billing impact at M&FC-O.

A complete, in-depth review of the program's budget was therefore performed. Actuals from inception to date were totaled to provide a baseline summary of program costs. This included some previously unrecorded costs, and the Budget and Manpower amounts previously reported in the POMTT 1st Quarter 2001 report were revised. Results of the review indicated that overall program invoices were within 2% of the budget at that stage (19 months) into the program. Although there were slight underruns in billing, cost share continued to be above contract-required levels. Also, IWTA invoices were being received sporadically so all the program participants were requested to examine their billing process to ensure invoices were being regularly submitted.

By the third quarter of 2001 invoices were coming in more regularly however, delays in tool availability and manpower issues contributed to the program in spending less that anticipated at both the Dallas and Orlando sites. To accommodate these delays, in the fourth quarter of 2001 the spending plan was again revised to move $117K of Dallas funds and $50K of 2001 Orlando funds to the 2003 budget.

In the first quarter of 2002 the Cost Methodology Plus-up began and its funding started being included in the POMTT spend plan. By the third quarter of 2002 a July mid-year review showed that the program was on schedule with approximately 67% of the total funds spent.

Through 2003 the program spending was according to plan, but in late 2003 and early 2004 personnel were pulled off program and re-tasked which reduced manpower and associated costs for Dallas. This was quickly addressed, but resulted in a 60 day slip in completion of the Dallas pilots. Therefore, a 90-day no-cost extension was requested and approved to allow completion of the efforts.

Accrued costs for the entire program are as follows: (Inception thru 08/04)

LMMFC - Orlando			
Total Cost	2,593,889		
Government Cost		1,284,145	
Cost Share			1,309,744
LMMFC – Dallas			
Total Cost	1,562,765		
Government Cost		823,665	
Cost Share			739,100
BAE System Controls			
Total Cost	2,510,926		
Government Cost		1,160,787	
Cost Share			1,350,139
LM Launch Systems			
Total Cost	10,403		
Government Cost		10,403	
Cost Share			0
Manassas			
Total Cost	232,496		
Government Cost		118,596	
Cost Share			113,900
VP Technologies			
Total Cost	149,488		
Government Cost		119,877	
Cost Share			29,611
TOTALS	7,059,967	3,517,473	3,542,494
		(49.8%)	(50.2%)

The contract required a cost share percentage of 50.3% (maximum) for the government and 49.7% for Lockheed Martin. Therefore, the program again exceeded the contract requirements.

Total of LMM&FC-O invoices submitted to the Government: $3,499,787